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Clinical Microbiology Laboratories' Transition to a Sustainable Future

A Case Study at Leiden University Medical Center

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Date of completion	January 31, 2023
Wordcount	13.544

Statement of originality

I, Yuanyuan (Alice) Wu, hereby declare that this thesis was written as an individual project and contains only original contents. All sources mentioned in the texts are properly referenced and cited. The copyright of the Master thesis rests with the author. The author is responsible for its contents. Rotterdam School of Management is only responsible for educational coaching and cannot be held liable for the content.

Acknowledgments

Writing this thesis has been a long yet rewarding journey for me. Coming from the US, this is my first year in the Netherlands, my first time doing a Master's, and my first time writing a thesis. I found my passion for sustainability in college and seeing the Covid-19 pandemic running rampant in the US made me take an interest in healthcare as well. So when I saw the opportunity to be a part of the Interdisciplinary Thesis Lab on Sustainable Hospitals, I applied for it right away. I've learned so much through this process, both in my understanding of sustainability in the healthcare setting and my ability to write academically. Throughout the months of working on this thesis, I encountered various personal difficulties which stalled my progress and challenged my motivation to finish. With that, I would like to thank my coach – Lucas Meijs. Without his understanding, patience, continuous encouragement, and guidance, I would not be able to bring my best work forward today. I would also like to thank my co-reader, mentors from the Thesis Lab, and LUMC employees that provided their valuable opinions for my research. Lastly, I would like to thank my peers in the Thesis Lab, namely Lisanne Wigchert, Rixt van der Giessen, Lieke de Rouw, Anouk de Reeder, Marleen Ungerathen, Robin Weij, Ingena Both, Elaine van Ee and Cathelijne Pallandt. Working with you girls gave me hope for a more sustainable future!

Abstract

The healthcare industry is highly emission-intensive and poses severe threats to the environment and society at large. The topic of sustainability is currently under researched in the context of healthcare; the knowledge gap is even deeper in its application to clinical microbiology laboratories. Using a qualitative research approach, this thesis aims to find out how clinical microbiology laboratories can move towards a sustainable future with a case study of Leiden University Medical Center and its microbiology labs. Data were collected and analyzed following the grounded theory framework. Findings suggested that stakeholder collaboration on an individual, organizational, and sectoral level is the key to success for sustainable transition at LUMC. Specific development strategies are outlined in the findings chapter. This thesis contributes theoretically to the extremely limited pool of existing literature on the topic of sustainable laboratories by employing a stakeholder view; practically by providing tailored advice that can lead to real changes at LUMC and its laboratories. Recommendations for future research include ensuring longevity to document the actual implementation outcomes of stakeholder strategies and taking a more proactive approach in investigating care pathways to promote health rather than passive disease prevention.

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List of Abbreviations

CDC	Centers for Disease Control and Prevention
CEEL	Center for Energy Efficient Laboratories
CSR	Corporate Social Responsibility
EMS	Environmental Management System
EU	European Union
FDA	Food and Drug Administration
GOSH	Great Ormond Street Hospital
HTA	Health Technology Assessment
LEAF	Laboratory Efficiency Assessment Framework
LEED	Leadership in Energy and Environmental Design
LUMC	Leiden University Medical Center
NHS	National Health Service
OR	Operating Room
POE	Post Occupancy Evaluation
PPE	Personal Protective Equipment
PPP	Public–Private Partnerships
QMS	Quality Management System
SDGs	Sustainable Development Goals
SSI	Semi-Structured Interviews
SUDs	Single-Use Medical Devices
TBL	Triple Bottom Line
UMCs	University Medical Centers
UNDP	United Nations Development Programme

1. Introduction

1.1 Climate Change Is a Public Health Crisis

As human activities continue to pollute the earth, the adverse effects are adding up and the negative consequences are becoming increasingly obvious. Natural disasters are occurring more frequently across the world as a result of climate change and there is a sense of urgency to take action. More people are becoming aware of the term "sustainability" and are looking for ways to incorporate that into their daily lives. In the United States, the annual share of sustainability-marketed products grew from 13.7% in 2015 to 16.8% in 2020 (Kronthal-Sacco & Whelan, 2021). Additionally, there has been a rise in governmental leadership, such as the creation of the European Union's Sustainable Development Goals (SDGs). However, amid all these efforts to move towards a more sustainable future, the healthcare industry has seemed to be forgotten.

Possibly due to all the benefits modern medicine has provided for humans – less death from curable diseases and longer average life expectancy – its negative impacts on the environment have been largely overlooked. Many medical practices nowadays are safer and more efficient at the expense of the health of the planet and its ecological system. For example, to save time from sterilization and to minimize the possibility of infections, many medical instruments have been redesigned. This is especially evident in a clinical microbiology laboratory setting, as lab instruments such as surgical gloves, pipettes, pipette tips, and culture dishes are now produced with plastic as the main material and are meant to be discarded after a single use. There has also been a huge amount of technological innovation in the healthcare industry which can also be problematic for climate change. Many medical machines require uninterrupted operation time which results in intensive energy use. Consequently, the negative environmental contribution of global healthcare now accounts for 1% to 5% of the world's total greenhouse gas emissions, and more than 5% for some nations

(Lenzen et al., 2020). More specifically, the sector has contributed 2.8% of harmful particulate matter (air particles), 3.4% of nitrogen oxides, and 3.6% of sulfur dioxide globally (Capon et al., 2020). In the United States, healthcare buildings alone consume "9% of the total primary energy consumption for all commercial buildings" (Lopez et al., 2017, p. 3).

It is evident that while the healthcare industry vows to do no harm, degradation of the natural environment has emerged as an unintended consequence. As climate change worsens and the state of the environment slips into rapid decline, devastating public health events like the Covid-19 global pandemic will only occur more frequently in the future. According to U.S. Global Change Research Program (2016), "climate change can therefore affect human health in two main ways: first, by changing the severity or frequency of health problems that are already affected by climate or weather factors; and second, by creating unprecedented or unanticipated health problems or health threats in places where they have not previously occurred" (p. 4). Climate change has been viewed largely as an environmental issue, but it is becoming a public health crisis as well. The healthcare industry's vow to do no harm needs to be applied to not only human beings, but also the planet itself. Actions in pursuing a more sustainable future for the healthcare industry cannot be delayed anymore, as the health of mankind and the health of the planet are interdependent. An inhabitable earth cannot and will not be the home to healthy humans.

1.2 Research Objective & Structure

Many academic scholars and healthcare workers have gained awareness of the current situation and are looking for solutions. An example of that would be Medical Delta – founded in 2006 by three universities: TU Delft, Leiden University, and Erasmus University Rotterdam, as well as two University Medical Centers: Leiden University Medical Center (LUMC), and Erasmus Medical Center. Since then, four additional universities of applied

sciences joined as well, all reaching for the common goal of realizing “sustainable care with technological solutions” (Medical Delta, 2022). This thesis is a part of the Interdisciplinary Thesis Lab on “Sustainable Hospitals” commissioned and supervised by Medical Delta, along with the LDE Centre for Sustainability – a multidisciplinary Research, Education and Valorization Center run by the three universities mentioned above (LDE Centre for Sustainability, n.d.). Along with ten other master’s students, the Interdisciplinary Thesis Lab aimed to answer the question of “how do we create a sustainable hospital” from different perspectives (LUMC Global, 2022).

More specifically, this thesis set out to investigate the pursuit of Sustainable Hospitals in a clinical microbiology laboratory setting, with LUMC as the subject to conduct a single case study. With that in mind, the below research question was developed:

How can clinical microbiology laboratories move towards a sustainable future?

Qualitative research was carried out starting with an extensive literature review to build up a strong theoretical background on both the current impacts of healthcare organizations and microbiology laboratories and the strategies for achieving sustainable transition. The research methodology included a case study approach; data were collected and analyzed using the grounded theory framework. The proposed research question was answered in the findings section by using data and literature as supporting evidence. Practical and theoretical contributions, along with limitations and recommendations for future research were discussed in the last chapter – discussion.

2. Literature Review

This chapter investigates past literature on three subjects respectively. The first section discusses the healthcare sector's negative environmental and social impacts, which further confirmed the relevance of this study. The focus then shifts to sustainable solutions for the healthcare industry as a whole and hospitals specifically, with a strong emphasis on stakeholder strategies. Lastly, literature on the main focus of this thesis – sustainable laboratories are investigated, and a knowledge gap was identified which provided the directions needed to conduct further research.

2.1 Healthcare Sector's Negative Impacts

While the healthcare sector vows to do no harm and modern medicine continues to improve the health of the global population, unintended negative consequences are borne by the environment, as well as society in the long term. The following sections discuss the healthcare sector's negative environmental and social impacts respectively.

Environmental Impacts

In 2014, the carbon footprints generated by global healthcare were equivalent to the annual emissions from 514 coal-fired power plants and accounted for 4.4% of the global net emissions (Health Care Without Harm & Arup, 2019). In the Netherlands specifically, the sector is responsible for 7% of the nation's total CO_2 footprints (Yusuf et al., 2022). Energy use – in the forms of electricity, gas, steam, and air conditioning, primarily provided by the combustion of fossil fuels – makes up more than half of the sector's total footprint. Healthcare facilities directly contribute to 17% of global healthcare's emissions, while 12% indirectly come from purchased energy sources, and a striking 71% are emitted by the global

healthcare supply chain which entails the production, transportation, use, and disposal of goods and services (Health Care Without Harm & Arup, 2019).

Taking a closer look at hospitals' climate impacts specifically, Keller et al. (2021) identified the top contributing activities as heating, catering, infrastructure, medical products, housekeeping, and waste. Healthcare-related buildings in the US use 2.7 times more energy annually than regular commercial buildings and account for 9% of the nation's total primary energy consumption for all commercial buildings (Lopez et al., 2017). In terms of waste, it has been reported that hospitals generate more than 5 million tons of waste every year and over 29 pounds of waste per hospital bed daily (Practice Greenhealth, n.d.). World Health Organization (2018) estimated that 85% of healthcare waste is general waste, and 15% is considered hazardous which could potentially be infectious, toxic, or radioactive, which requires proper waste management to eliminate safety concerns. Inadequate disposal of untreated hazardous waste can pose public health risks, and lead to environmental contaminations of water and air. At the same time, those negative impacts can also be caused by the current standardized treatment of special hospital waste – incineration (World Health Organization, 2018). Furthermore, to limit infections, the healthcare industry now relies heavily on single-use disposables, primarily made out of plastics (ECHAlliance, 2021; Pencheon, 2009; Percival, 2019). Keller et al. (2021) found that disposable drapes and surgical drape kits are responsible for 14% of the climate impacts caused by medical products, and 7% for single-use scrubs. UK's National Health Service (NHS) generates about 133,000 tons of plastic annually – counting for 22.7% of the nation's total healthcare waste – however, only 5% is currently being recycled (ECHAlliance, 2021; Percival, 2019).

Social Impacts

Global healthcare's unsustainable practices have not only negatively impacted the environment, but also society as a whole. Lenzen et al. (2020) identified seven environmental stressors caused by the healthcare sector, including greenhouse gas emissions, particulate matter, air pollutants (nitrogen oxides and sulfur dioxide), malaria risk, reactive nitrogen in water, and scarce water use. While carbon emissions contribute to climate change which indirectly impacts human health in the long term; air and water pollution does so more directly. World Health Organization (2019) reported that 23% of all deaths around the globe could be prevented with healthier environments; more specifically, one in eight deaths is caused by air pollution, over 1.6 million are caused by exposure to chemicals, and more than 2 billion people's water sources are contaminated. This dilemmatic relationship between healthcare and the environment has been described as the cycle of adverse feedback – the more healthcare-related activities occur, the more damage is done to the environment, which would in turn negatively impact human health and create an even direr need for healthcare services (Lenzen et al., 2020). Every single stakeholder within the global healthcare system has a responsibility to reduce their environmental footprints, or else devastating public health emergencies like the Covid-19 pandemic will only occur more frequently. Climate change is a public health crisis, and the world has recently witnessed how vulnerable communities were disproportionately affected – both in terms of the severity of impact and the access to quality medical care. Stakeholders from high-income countries like the Netherlands have far more resources and technical advancements, and thus a greater responsibility in making healthcare more sustainable.

2.2 Drivers of Sustainable Change in Healthcare

Although there is a large pool of existing literature on the topic of sustainability, a knowledge gap was identified in its application to the healthcare sector (Borges de Oliveira &

de Oliveira, 2022; Lopez et al., 2017; Marimuthu & Paulose, 2016; Mehra & Sharma, 2021). As global healthcare continues to contribute to climate change, scholars have been investigating what sustainable healthcare means in all three dimensions of the Triple Bottom Line (TBL) framework – social, environmental, and economic (Borges de Oliveira & de Oliveira, 2022; Mehra & Sharma, 2021; Weisz et al., 2011). How could the sector continue to improve healthcare services while ensuring environment conservation, efficient resource management, and cost-effectiveness? In answering such a complex and multidimensional question, existing literature aligned with the central theme of carbon reduction (Health Care Without Harm & Arup, 2019; Mehra & Sharma, 2021; Pencheon, 2009). The following sections discuss the various opportunities and challenges identified for the pursuit of sustainability in healthcare.

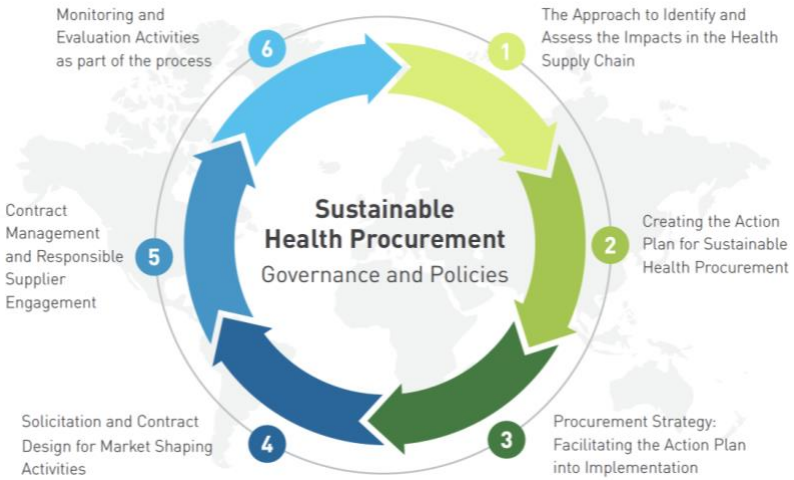
Sustainable Procurement & Circularity

Oruezabala & Rico (2012) defined sustainable procurement as "the efforts of an organization to achieve or simply improve performance of buying activities in three ways: environmentally, socially and economically" (p. 574). For healthcare organizations such as hospitals, sustainable procurement can be extremely challenging due to the focus on patient safety which has led to the shift towards plastic disposables and single-use products (PVCMed Alliance, 2020). As mentioned before, medical disposables have a huge contribution to climate change and are not being adequately recycled; changes need to be made. Luckily, there are existing guidelines to make such transition easier for healthcare organizations, such as the *Sustainable Procurement in Health Care Guide* which uses the "plan-do-check-act" framework to provide a roadmap for "a systematic approach to operationalizing sustainable procurement" (Health Care Without Harm, 2017). Another example is the *Sustainable Health Procurement Guidance Note* provided by the United

Nations Development Programme (UNDP), which included a chronological step-by-step plan shown in figure 1. Emphases were placed on several keys to success, namely a strategic level of planning, management support, appropriate capacity building amongst stakeholders, and interdisciplinary efforts (United Nations Development Programme, 2020).

Figure 1

The Sustainable Health Procurement Approach Plan by UNDP



Note. Adapted from *Sustainable Health Procurement Guidance Note*, by United Nations Development Programme, 2020, *UNDP*, (https://www.undp.org/publications/guidelines-sustainable-procurement-healthcare-commodities-and-services).

Echoing step 5 of the *Sustainable Health Procurement Guidance Note* shown in the figure above, scholars proposed a necessary shift towards circularity for healthcare-related products (Elabed et al., 2019; Healthcare Plastics Recycling Council, 2020; Kane et al., 2018; MacNeill et al., 2020; Mehra & Sharma, 2021; Ranjbari et al., 2022; van Straten et al., 2021). In circulation, the used resources and environmental costs of medical products are distributed over time, in turn maximizing the added value in each product life (MacNeill et al., 2020). Circular practices include reducing primary resource usage, preventing waste, maintaining

healthcare-related products and materials at the highest value, changing utilization patterns, and sharing healthcare products (Mehra & Sharma, 2021). The responsibilities to implement these practices fall on not only the healthcare sector but also the market and waste management companies. From the design and production stage of a product's life cycle, circular considerations should already be embedded, such as the use of specific materials, the potential for recycling, reselling, repurposing, repairing, refurbishing, remanufacturing, and recovering (van Straten et al., 2021). Healthcare organizations then have the responsibility for both sustainable procurement and conscious usage of resources, including practices like refuse, rethink, reduce, and reuse (Morseletto, 2020). Furthermore, proper waste management is essential in closing the loop of circularity, which requires the joint efforts of both healthcare organizations and waste management companies to maintain the integrity of product materials and the subsequent re-harvesting (Elabed et al., 2019; Ranjbari et al., 2022).

Unfortunately, scholars have identified a research gap in the application of circular principles to the healthcare industry due to the "clinical challenges of safety and sterility" (Kane et al. 2018, p. 38). Existing regulations on patient safety have posed challenges for both medical suppliers in designing circular products, and for healthcare organizations in attempting circular practices independently (Borges de Oliveira & de Oliveira, 2022; Kane et al., 2018). However, there is hope for the future. With increasing oversight by the US Food and Drug Administration (FDA), available data have shown that reprocessed single-use medical devices (SUDs) do not present an elevated health risk (Kaplan et al., 2012). The FDA has also released a regulatory guideline on the reprocessing of single-use medical devices for hospitals and third parties (FDA, 2000). In terms of circular waste management, Healthcare Plastics Recycling Council (2020) echoed the challenges of performance characteristics, traceability, market limitations, and regulatory constraints; identifying

opportunities for the future including non-sterile healthcare applications for recycled content, improved recycling infrastructure, and new recycling technologies. A strong emphasis was placed on the individual responsibilities of stakeholders and the power of collaboration regarding the recycling of medical plastics; key players were identified as customers, customer trends in the European Union (EU), legislation, and manufacturers (Healthcare Plastics Recycling Council, 2020).

Sustainable Healthcare Facilities

The design of a hospital building (materials used, insulation, availability of sunlight, cooling systems, etc.) can directly impact the health of staff and patients who spend countless hours within it, and indirectly affect the surrounding communities and the general public through emissions, wastes, and pollutions (Balali & Valipour, 2021; Brambilla & Capolongo, 2019; Hamilton, 2008; Stevanovic et al., 2017). Vittori (2002) proposed the redefining of sustainability in healthcare facilities by analyzing the lifecycle of building materials from both environmental and social aspects. There are readily available evaluative tools like the US Green Building Council's Leadership in Energy and Environmental Design (LEED) certification, which addresses carbon, energy, water, waste, transportation, materials, health, and indoor environmental quality (U.S. Green Building Council, n.d.). Brambilla & Capolongo (2019) on the other hand, utilized Post Occupancy Evaluation (POE) tools to assess the health and sustainability of hospitals' built environment. To maximize the sustainable capability of a healthcare facility, strategies should be actively implemented from the design phase. However, for existing and working hospitals, Balali & Valipour (2021) outlined passive strategies for sustainable design and found three main opportunities for improvement – thermal, acoustic, and lighting. Specific strategies included reducing energy consumption, compatibility with climate, durability, optimizing fenestration design, using

naturally-ventilated envelopes, and using sun shading devices (Balali & Valipour, 2021). These facility changes usually require large capital investments due to the premium prices of sustainable products and materials, which could be a concern for healthcare organizations with limited budgets. Vittori (2002) argued that hospital owners and providers must make an accounting shift from "first-cost" to "full cost" – weighting the initial investments over the lifetime of the building considering the provided long-term benefits like enhanced productivity, better health-related outcomes, and reduced environmental impacts (p. 2). The author further pointed out the importance of partnerships with suppliers and design professionals to continue discovering the sustainable design of healthcare facilities (Vittori, 2002). In the example of St. Mary's Hospital Medical Center, partnering with community leaders led to financial assistance through the Focus on Energy grants, which helped the hospital purchase energy-saving equipment (Hamilton, 2008).

Energy & Water Use Reduction

As one of the most important and influential stakeholders of the healthcare sector, Borges de Oliveira & de Oliveira (2022) described hospitals as "the central link in the healthcare service delivery chain" (p. 2). By operating 24 hours a day uninterruptedly, they consume an enormous amount of energy and water. Existing research has identified various reduction strategies such as high-quality insulation, motion-sensitive lighting, motor upgrades, off-hours shutdown, steam insulating jackets, wastewater treatment, and water conservation (Kaplan et al., 2012; Pencheon, 2009; Rodríguez et al., 2021). The actual implementation can vary for hospitals depending on the location, state of the facility, and available budgets. Interventions mentioned previously would be easier to adopt for new hospitals that can install high-efficiency systems from construction. Practices such as solar film on windows and hydronic heating controls could be impractical for hospitals located in

regions with low sunlight or extremely cold weather (Kaplan et al., 2012). Hospital employees along with management should first identify the hotspots for energy and water use, then look for feasible interventions with the help of guidelines like ISO 14001 (Environmental Management) and ISO 50001 (Energy Management).

Organizational Management

For healthcare organizations like hospitals, senior management has been identified as an essential driver of sustainability (Borges de Oliveira & de Oliveira, 2022; Kaplan et al., 2012; Rodríguez et al., 2021; Weisz et al., 2011). Quality Management System (QMS) has long been used by hospitals to ensure operational excellence; scholars proposed to move sustainability into the core business and establish quality criteria for social, ecological, and economical sustainability (Rodríguez et al., 2021; Weisz et al., 2011). Such integration requires hospital management's leadership in initiating change and monitoring progress continuously (Weisz et al., 2011). Furthermore, Borges de Oliveira & de Oliveira (2022) demonstrated the importance of knowledge management in healthcare organizations, which entails the structured management of intellectual capital in the dimensions of human, structural, and relational. Hospital employees can be a valuable source of sustainable innovation and play a key role in the hospital's performance through efficient use of resources, knowledge sharing, and the implementation of sustainable initiatives. On the other hand, stakeholder knowledge is just as essential; external perspectives can increase hospitals' expertise on sustainable development and boost change through collaboration during decision-making processes (Borges de Oliveira & de Oliveira, 2022).

With the existing research gap on sustainability in healthcare, hospitals can greatly benefit from the adaptation of existing management systems developed based on academic research and tested by other sectors' implementation. Borges de Oliveira & de Oliveira

(2022) outlined several management models that can be applied to healthcare, including public–private partnerships (PPP), Health Technology Assessment (HTA), and Lean Six Sigma.

Culture & Mindset Shift

Although many drivers of sustainability in healthcare require capital investments, some are achieved with a simple culture or mindset shift. Kaplan et al. (2012) argued that commitment to sustainability should be made on an organizational level, set by the hospital board, and followed by all the involved stakeholders (staff, medical personnel, external partners, etc.). Green practices such as shut-downs at the end of workdays, less paper use, emission-free travel, and conscious medical instrument usage only require a mindset shift in individuals at the hospital. A top-down organizational culture shift towards corporate social responsibility (CSR) would integrate sustainability into the mission, vision, and policies of hospitals, thus further inspiring change among individuals and avoiding potential pushback (Borges de Oliveira & de Oliveira, 2022).

Research & Innovation

Research and innovation for sustainable healthcare can be divided into two categories – medical and non-medical related. Technologies like real-time energy consumption tracking software and automated weighing systems in waste management should be considered at hospitals pursuing sustainable procurement and facilities (Borges de Oliveira & de Oliveira, 2022). Medical research and innovation, on the other hand, are much needed for many of the above-mentioned sustainable initiatives to be feasible. For example, van Straten et al. (2021) suggested further research on circular instrument management's true impacts on both energy consumption and carbon footprint to understand the cost and benefits of circular practices.

CDC (2016) cautioned healthcare workers that the reuse of disposable medical devices is still in need of further research and the relevant regulations are still evolving.

An interesting finding emerged on the current passive approach to medical innovations – mostly in facing diseases and infections. Mehra & Sharma (2021) advocated for a more proactive approach in "universalizing preventive healthcare through personal hygiene, awareness, vaccination, regular check-ups, and promotive healthcare through exercise, yoga, meditation, and healthy food" (p. 4). Hospitals equipped with the appropriate technological innovations such as telemedicine, electronic medical records, AI & machine learning, etc. can help patients take control of their own health through self-monitoring and remote professional supervision (Borges de Oliveira & de Oliveira, 2022; Khan, 2022; Pereno & Eriksson, 2020). Pencheon (2009) reported that traveling by healthcare workers, patients, and visitors contributes up to 20% of the sector's total carbon footprint. Preventive and promotive healthcare can improve both social and environmental sustainability through reduced visits to hospitals and the promotion of active low-emission traveling methods like electric vehicles, public transportation, cycling, and walking (Mehra & Sharma, 2021).

2.3 Sustainable Laboratories

Narrowing the focus to the main subject of this thesis – sustainable clinical microbiology laboratories, existing literature presented an even deeper knowledge gap (Lopez & Badrick, 2012; Lopez et al., 2017; Molero et al., 2021; Yusuf et al., 2022). Most of the challenges and opportunities identified for sustainable development in a laboratory setting have been the same as those for healthcare organizations. Since most of the clinical laboratories operate within a hospital, this finding was not surprising. Challenges like the lack of knowledge and awareness for sustainable practices, regulations hindering initiatives, limited budgeting, and the need for more research and innovation on medical practices were

present in a laboratory setting as well (Lopez & Badrick; 2012; Lopez et al., 2017; Molero et al., 2021; Yusuf et al., 2022). Scholars advocated for the implantation of the Environmental Management System (EMS) or an environmental policy to integrate social, environmental, and economic sustainability considerations into all the lab's activities (Lopez & Badrick, 2012). The three keys to success for such management systems were identified as long-term senior management support, engaging the lab workforce through public commitments to sustainability, and resource & impact monitoring (Lopez & Badrick; Yusuf et al., 2022). To best monitor and reduce the carbon footprints of laboratories, scholars suggested the calculation of emissions per performed test, as well as a rational test ordering policy (Molero et al., 2021; Yusuf et al., 2022). Past studies have shown that revisions of lab test ordering policy through decreased convenience of ordering or best-practice alerts can lead to both resource and financial savings (Bejjanki, et al., 2018; Blumberg, et al., 2019, as cited in Molero et al., 2021). Furthermore, the previously discussed drivers of sustainable hospitals – namely sustainable procurement, facility, waste management, and stakeholder strategies – have all been deemed as essential for the success of sustainable laboratories as well (Lopez & Badrick; 2012; Lopez et al., 2017; Yusuf et al., 2022). The most prominent opportunity, however, entailed interdisciplinary research and innovation in the development of sustainable integrated care models for clinical laboratories. Molero et al. (2021) argued that labs should actively participate in disease prevention by defining and assessing laboratory tests and processes' added value, which should not be measured by the cost per episode of care, but by social and environmental sustainability measures. This can be achieved with the help of technological innovations such as AI tools and automated lab systems (Molero et al., 2021).

Beyond literature, there are some existing guidelines and resources for sustainable clinical laboratories such as My Green Lab Certification, The Center for Energy Efficient Laboratories (CEEL), Laboratory Efficiency Assessment Framework (LEAF), and S-Lab

Environmental Good Practice Guide. These models have been developed based on research and tested by real implementation at labs. For example, the LEAF certification assists laboratories estimate their current sustainability performance and tracks improvements in the areas of waste, travel, energy, water, procurement, and research quality. It also provides training and tailored workshop for participating labs to increase user engagement (UCL, 2022). LEAF pilot studies in the UK and Ireland from 2018 to 2020 reached 235 labs across 23 institutes and resulted in 648 tons of carbon reduction and financial savings of £641000 (Green Labs NL, 2022). Laboratories that are just starting to incorporate sustainability into their operation can greatly benefit from these guidelines to ensure the maximum positive returns and avoid any obstacles.

3. Methodology

With an extensive review of past literature, the previous chapter provided the strong theoretical background needed to conduct further research on what sustainability means in the healthcare sector, and more specifically in a clinical microbiology laboratory setting. In this chapter, the research methodology adopted in this thesis is discussed in detail, specifically in the order of – research design, case study, data collection & analysis.

3.1 Research Design

During research design, qualitative research was chosen for various reasons. The rationalities are discussed in more detail as follows.

Since the research question of this thesis started with the word "how", the answer wasn't a simple yes or no – it required an investigation of the process needed to reach a certain end goal. As described by Queiros et al. (2017), qualitative research places a strong focus on understanding and explaining the "dynamics of social relations" – aspects of reality that are not quantifiable. The transition towards sustainability is a complex social and environmental problem that involves countless stakeholders. It couldn't be measured or analyzed using only numerical values or calculations. An identifying feature of qualitative research is an ontological position described as constructionist. Researchers need to "see through the eyes of one's research participants" (Bryman, 2012, p. 401). Rather than adopting a natural scientific model and testing it with quantifiable data, the theory of qualitative research is an outcome of the research rather than something that precedes it (Bell et al., 2019, p. 357). Qualitative phenomena and frameworks cannot stand alone from the stakeholders involved in their construction. Blumer (1954) argued that adopting an existing qualitative framework in social studies could be overly restrictive and researchers should only use it to gain "a general sense of reference and guidance in approaching empirical instances"

(p. 7). This was the precise goal of the literature review chapter – to provide a strong theoretical background for further research. The framework of this thesis was developed after the collection and analysis of data and would be presented and discussed in later chapters.

As previously established, there is currently a research gap for the overarching concept of sustainability in healthcare. Granted, sustainability has become a buzzword in academia in recent decades and researchers have been imagining how it could be applied to different industries. However, its translation into a hospital setting and the healthcare sector as a whole has been fairly limited. This was even more evident in the ever-narrower focus of clinical microbiology laboratories. This research gap has created a demand for further studies and more crystallized concepts, which was why this thesis is largely explorative – making data collection more challenging than quantitative research. As previously explained in the introduction chapter, this thesis is a part of a larger project – the Interdisciplinary Thesis Lab, which has provided the perfect opportunity to conduct research at LUMC. The findings of this study should serve as guidance and inspiration to achieve organizational change at the University Medical Centers (UMCs), as well as other healthcare organizations that also want to pursue a sustainable future.

3.2 Case Study

The decision to conduct a case study came quite naturally for a couple of reasons. As previously mentioned, sustainability in a clinical microbiology laboratory setting is currently under-explored in academia. Many organizations and individual stakeholders have little to no knowledge of what sustainability means for the healthcare industry. Amongst the ones that are aware, not enough are interested in or willing to make changes for the future. Thus, the ideal environment to collect data for this thesis was hard to come by. Furthermore, with the time and resource constraints in mind, it was not feasible to conduct adequate research at multiple

hospitals. As explained by Lazar et al. (2017), “the substantial effort needed to conduct a thorough investigation of each case leads directly to a practical limit on the number of cases that can be included in any given study” (p. 156). A conscious decision was then made to carry out a single case study, prioritizing the depth and thoroughness of the findings rather than their generalizability on a larger scale.

Stake’s 1995 study (as cited in Bell et al., 2019) suggested that when selecting the subject for a case study, the most important factor should be the potential opportunities for learning. Being a part of an Interdisciplinary Thesis Lab provided the opportunity to conduct close observation and field research, as well as organized lectures, excursions, and meetings with stakeholders – all taking place on-site at LUMC. The hospital’s participation showed great initiative and willingness to cooperate, which has been fundamental for the success of this study. The ultimate goal was to provide insights and suggestions that would guide LUMC and the relevant stakeholders toward becoming a sustainable hospital. Lazar et al. (2017) believed that case studies can be invaluable in providing feedback on a problem that is not yet well understood – as the researcher observes how participants of the study “currently accomplish tasks, use available tools, and respond to problematic situations”, insights can be gained to “inform both system design and future investigation” (p. 160). Although the final findings could be applied to other hospitals or even the healthcare industry as a whole, the main priority was placed on solving the specific challenges at LUMC. Especially considering that it is a university medical center focusing on not only patient care but also research and education.

With the above rationales in mind, a single case study was chosen with LUMC and its clinical microbiology laboratories as the subjects of interest.

3.3 Data Collection

Yin (2009) described six important sources of evidence for case studies, including documents, archival records, direct observation, participant observation, and physical artifacts. He believed that the quality of a case study could be increased substantially by using multiple sources of evidence conveying the same facts or findings. Such an approach has been referred to as triangulation by many scholars, such as Kanter (1977). The author explained how using a combination of different methods and cross-checking them allowed her to find "the most valid and reliable way" in understanding complex social realities (p. 337, as cited in Bell et al., 2019). With that in mind, the following sections describe how three sources of data were collected for this study, namely: in-person fieldwork, archival records, and semi-structured interviews.

In Person Fieldwork

Atieno (2009) described in-person fieldwork as physically going to "the people, setting, site, or institution to observe or record behavior in its natural setting" (p. 14). The Interdisciplinary Thesis Lab organized and hosted various events, including in-depth lectures, excursions, and meetings with stakeholders (see Appendix A). The in-depth lectures took place mostly on-site at LUMC and were delivered by either employees of the hospital or professors from one of the participating universities. They provided informative insights on different aspects of sustainable healthcare in general and shared their experiences specific to LUMC's sustainable transition journey thus far. At the end of each lecture, time was given for all participants of the Thesis Lab to ask questions. While actively participating in the lectures, notes and occasionally photographs were taken for later analysis.

Furthermore, through LUMC's active cooperation, the researcher was able to conduct direct observation at the clinical microbiology laboratories during normal workdays. Notes were taken on the physical layouts, how employees worked individually, and how they

interacted with each other. The researcher also participated in two group tours along with other students of the Thesis Lab. The first one took place at Van Straten Medical – a Dutch manufacturer and supplier of surgical instruments and disposables, with the mission of "providing value to life" (Van Straten Medical, 2022). The first part of the tour consisted of a presentation explaining the company's vision of applying circularity to medical instruments. The researcher then visited various departments of the company to observe its operation in real-time. The second group tour took place at LUMC's Central Sterilization Service and the Waste Management department. The researcher was able to observe the sterilization process for used medical instruments in real-time, from cleaning to repackaging. While visiting the Waste Management department, photographs were taken for the visual representation of the amount of waste generated by the hospital on that given day. Further information was then given on matters such as waste separation, recycling, and related regulations. Notes were taken throughout all the above-mentioned tours.

Due to the limited time and opportunities for notetaking during in-person fieldwork, field notes gathered during the above-mentioned activities were scattered and written in spoken language with some abbreviations. Afterward, the researcher went back and sorted through all the notes by adding missing information, correcting writing mistakes, and converting spoken information into academic languages. The field notes for each activity were organized in individual documents coded in chronological order as shown in Appendix B.

Semi-structured Interviews

Newcomer et al. (2015) described semi-structured interviews (SSI) as dialogues with one interviewee at a time, employing "a blend of closed- and open-ended questions, often accompanied by follow-up *why* or *how* questions" (p. 493). The interviewer shouldn't be

restricted to verbatim questions, but rather let the conversation meander around the topics of interest. Stakeholders interviewed in this thesis were given the freedom to expand on their answers, which sometimes led to valuable unforeseen insights. This approach also allowed interviews to flow more naturally and conversationally, creating a relaxed and engaging experience for the participants. As sustainability could be a touchy subject for some, SSI was chosen as the second data collection method to ensure that stakeholders felt comfortable sharing their most genuine and authentic experiences and opinions.

Appendix C includes the various interview guides developed depending on the specific role of the targeted interviewees. The researcher started with a quick self-introduction, followed by an overview of this thesis's research objectives. The interviewee was then asked for permission to record the interview and informed about their anonymity rights. After briefly going through the structure of the interview, the researcher dived into the different topics outlined in the interview guide. The duration of the interviews ranged from approximately 35 to 50 minutes. The recordings were first automatically converted into texts using the transcribe feature in Microsoft Word for Web. The researcher then manually corrected errors and inconsistencies by comparing the transcript to the original recording. It's worth noting that although all the interviewees were Dutch, interviews were conducted in English to accommodate the researcher's language barrier. Appendix D gives an overview of the semi-structured interviews conducted in the study and the corresponding codes.

Archival Records

Archival data is a great source of evidence when studying a public organization with open-access records, which is the case for LUMC (The Community Tool Box, n.d.). LUMC's annual reports were found on the hospital's websites as public records and special attention was given to the sections related to sustainability specifically. Employees at the microbiology

labs also provided various internal documents on green initiatives at the hospital, such as promotional materials, department email communications, and photographs from different projects. Archival data served as supplementary evidence and were searched for as needed.

3.4 Data Analysis

This thesis adopted the grounded theory framework for both data collection and data analysis. The following sections first explain that process in more detail, then describe how data are coded following the techniques adopted from Gioia et al. (2012).

Grounded Theory

Strauss and Corbin (1998) defined grounded theory as "derived from data, systematically gathered and analyzed through the research process. In this method, data collection, analysis, and eventual theory stand in close relationship to one another" (p. 12). Bell et al. (2019) identified its two central features as the development of theory out of data and an iterative or recursive approach in the data collection and analysis process; then listed the four key steps of constructing grounded theory research – theoretical sampling, coding, theoretical saturation, and constant comparing.

Glaser and Strauss (1967) described theoretical sampling as "the process of data collection for generating theory whereby the analyst jointly collects, codes, and analyzes his data and decides what data to collect next and where to find them, in order to develop his theory as it emerges" (p. 45). By nature, grounded theories are built from the ground up. However, the open-endedness can make the data collection process more challenging in the beginning. Luckily, this challenge was not encountered during this study credited to the researcher's participation in the Interdisciplinary Thesis Lab. The initial stage of data collection and analysis through in-person fieldwork led to the fundamental understanding of the current situation at

LUMC, and the identification of relevant stakeholders. It provided directions to further collect and analyze additional data through interviews and archival records until different themes of sustainable healthcare started to emerge. The next key steps in constructing a grounded theory according to Bell et al. (2019) are coding, constant comparison, and theoretical saturation. They go hand in hand and happen in a recursive process. Coding in a qualitative study involves the process of breaking down data into different themes while constantly comparing them to ensure adequate theoretical elaboration. When the existing data can sufficiently support the emerging concepts, theoretical saturation is reached (Bell et al., 2019).

Data Coding

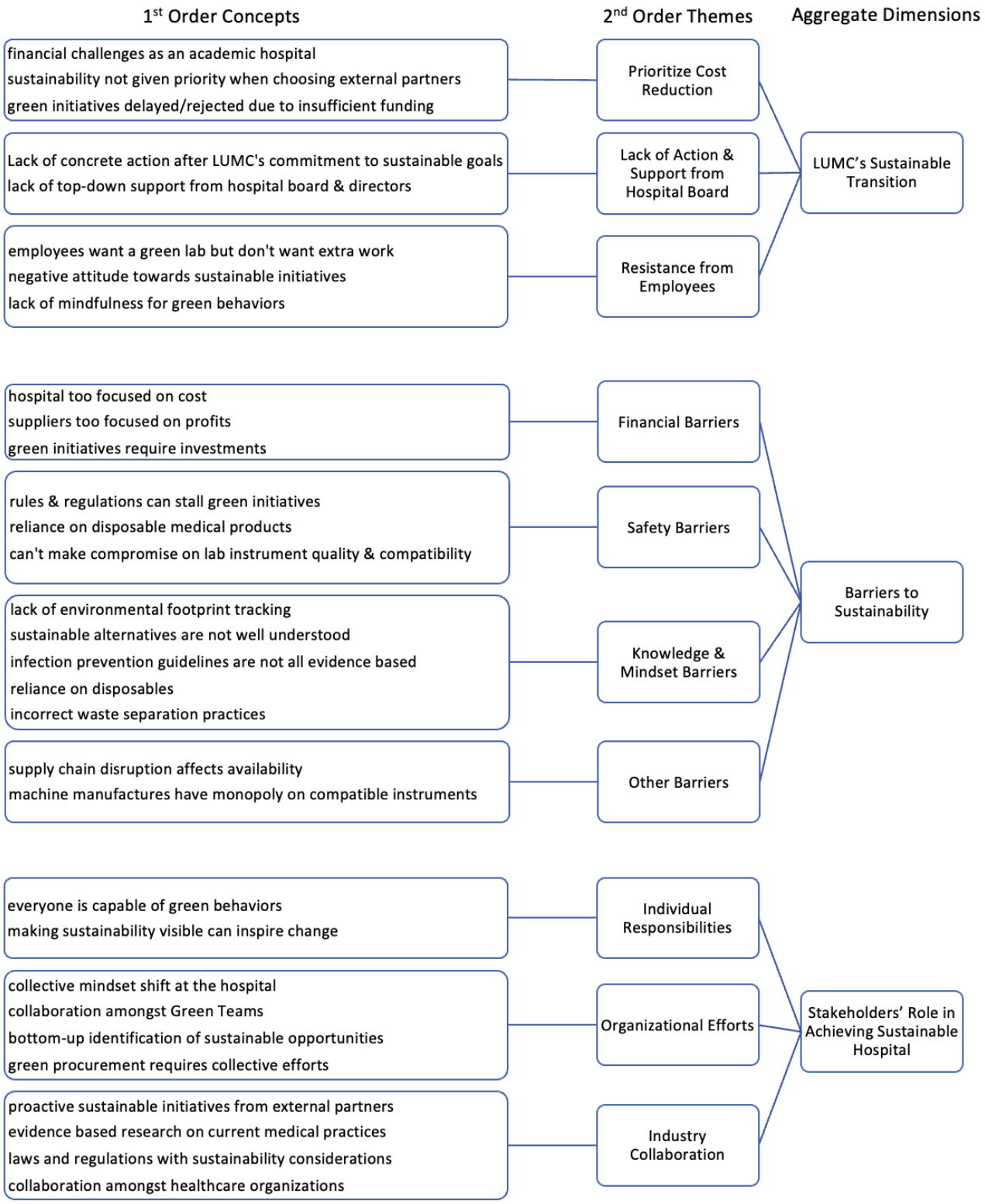
The data coding process of this study followed the techniques outlined in Gioia et al. (2012) and utilized qualitative data analysis software Delve. Gioia et al. (2012) using grounded theory, organized data into three categories: 1st order concepts, 2nd order themes, and aggregate dimensions. 1st order concepts tend to emerge in large numbers as the researcher should adhere faithfully to the data itself. As more concepts are discovered, their similarities and differences start to present which allows them to be grouped based on the themes they fit into. 2nd order themes should then be in a more manageable number and are concerned with the data's theoretical implications. They are often phrasal descriptors that can help explain the phenomena being observed in the study. The last category – aggregate dimensions are developed as theoretical saturation is achieved and 2nd order themes are distilled even further into only a handful of overarching aspects of the research subject (Gioia et al., 2012).

Following Gioia et al. (2012)'s technique, all three sources of data collected in this thesis were uploaded into analytical software Delve which allows individual quotes to be highlighted and assigned to the appropriate 1st order concepts. As themes started to emerge,

2nd order codes were developed, and using Delve's "merge" function, the corresponding 1st order codes were appropriately grouped with ease. Lastly, a document containing both 1st and 2nd order codes with organized corresponding quotations was downloaded to be further reviewed and refined into the final aggregate dimensions. All the information was then constructed into the coded data structure shown in figure 2, serving both as a "sensible visual aid" of the data analysis results, and a graphic representation of the iterative process of constructing a grounded theory (Gioia et al., 2012, p. 20).

Figure 2

Coded Data Structure of Semi-structured Interviews



4. Findings

This thesis set out to answer the research question of "how can clinical microbiology laboratories move towards a sustainable future?" with a case study on LUMC's sustainable transition. Through an extensive literature review and the subsequent research conducted within the grounded theory framework, this chapter discusses the research findings and the researcher's interpretations. All sources of data collected – namely in-person fieldwork, semi-structured interviews, and archival records – were considered and cross-checked to increase results accuracy using triangulation.

Adhering to the coded data structure presented in the previous chapter, each of the following sections outlines a different theme of sustainable healthcare at LUMC and its clinical microbiology laboratories. The first two sections – LUMC's sustainable transition and barriers to sustainability – investigate the hospital's current sustainable performances and identify potential areas of improvement and the associated challenges. The third section is the core finding of this thesis and provides the answers to the research question, supported by collected data and relevant literature.

4.1 LUMC's Sustainable Transition

LUMC has not been unfamiliar with the concept of sustainability, even before its participation in the Thesis Lab project. According to LUMC's 2020 annual report, the hospital had many sustainable initiatives such as the LUMC Green & Healthy program which promoted green energy, purchasing circularly and offering pure and varied food (LUMC, 2020). Specific projects included a healthy food supply in the LUMC restaurant, a silver certificate from the National Environmental Thermometer Care, the Green Deal 2.0, a 60% recycling in 2022 goal, a 20% annual increase in green electricity purchase goal, new

sustainable operating room (OR) in 2024 goal, and Green Teams. The Green Deal 2.0 contains agreements to make healthcare more sustainable in the Netherlands based on four themes: “CO2-reductie, meer circulair werken, minder medicijnresten in het water en een gezonde leefomgeving voor patiënten en medewerkers” [CO2 reduction, more circular working methods, fewer medicine residues in the water and a healthy living environment for patients and employees] (p. 57). Employees at LUMC are encouraged to incorporate sustainability into their departments and are assembled as Green Teams to inspire change in others (LUMC, 2020).

During both in-person fieldwork and semi-structured interviews, participants shared their personal experiences and opinions on the current sustainable initiatives at LUMC. Three main themes emerged from the allocated answers and are discussed respectively as follows.

Prioritize Cost Reduction

LUMC as an academic hospital is funded by the Dutch Government, and tendering expenses is always a priority (I2). This unique financial position has left the hospital with a short horizon for budgeting and a short-term vision for sustainable development (F3). Elst (2021) reported that at the end of 2020, LUMC suffered a loss of 22 million euros; this downward trend was projected to continue if serious cuts weren’t made. To make the matter worse, the hospital had to pay a large portion of the medicine costs independently per the 2018 Hoofdlijnenakkoord [Outline Agreement] and received even less funding in 2021 for training and research purposes (Elst, 2021). As a last blow, all of these financial challenges were faced during the Covid-19 global pandemic which led to the total health expenditure (as a share of GDP) in the Netherlands growing from 13.1% in 2017 to 14.5% in 2021 (Statista, 2022).

Participants felt that while LUMC is under tremendous pressure to prioritize cost reduction at the moment, it has unfortunately hindered the pursuit of sustainability (F3).

"Due to serious cuts at LUMC and thus KML [clinical microbiology laboratory] we do not have a lot of space to invest in sustainability at the lab at the moment." – I4

The hospital's short-term vision is especially evident in the criteria used to choose external stakeholders such as suppliers and waste management. I2 pointed out that sustainable products and practices are often more expensive initially and the return on investment is generated over time. When a limited budget, LUMC tends to "stick to the old way" in order to achieve cost reduction, while sustainable development is put on hold (F3). Especially during the Covid-19 pandemic, participants reported how global supply chain disruptions led to procurement challenges in both cost and availability (F4).

"Price is number 1. And then sustainability is… also important, but not number 1. If you're not so sustainable but your price is really low, you'll get the job." – I1

"So it depends on when you buy what. […] sometimes we don't have the luxury of being able to buy a 20% more expensive product because it's very sustainable. So sometimes we need to discuss a lot." – I2

Interviewees shared a few specific examples of green initiatives at LUMC that were either delayed or rejected due to the lack of funding. The waste management department proposed the purchase of a machine that can process special hospital waste into regular cardboard with a thin layer of plastic. The initiative required an investment of €350,000 and was projected to have long-term positive environmental impacts by reducing both the incineration and transportation of contaminated waste and the associated emissions. Due to the large sum of investment required, LUMC did not approve the purchase at the time but expressed the possibility in 2024. Although I1 remained skeptical due to the hospital's increasingly limited budget and the priority of medical-related spending.

"I don't think it's going to happen in 2024 […] the priority is really the medical things, new stuff for medical treatment and things like that." – I1

Another example was given regarding office equipment where the hospital only supported the switch to more sustainable options that didn't cost more money, even when the difference was not significant.

"I wanted office equipment that is made of reused materials or plastic pens made of reusable plastic. I could do it, but not if it costed like 2 cents per pen more. So I did it for all the stuff that was the same price or less. […] It's not a lot, but that was the problem. Yes, you can do it, but only if the price is the same, it's OK. If it's more expensive, then no." – I1

An interesting point was brought up by I2 regarding external stakeholders' responsibilities in pursuing sustainable procurement. While hospitals are demanding more sustainable and affordable products from the market, most of LUMC's external suppliers currently view sustainability as an added value rather than a part of the core business. Such mismatch can also be attributed to the lack of knowledge on how to design and produce sustainable medical products (F3).

"Yes, it's getting more and more important, but not as much as we would like. Some see it as an added value so they would say oh, by the way, we are very interested, or we have a plan for sustainability." – I2

Lack of Action & Support from Hospital Board

As previously mentioned, LUMC has committed to many sustainable goals such as the Green Deal 2.0 and a 20% annual increase in green electricity purchases (LUMC, 2020). The interviewees, however, have witnessed a lack of concrete action following these commitments. The latest annual report published on the hospital's website is from 2020 and

there has not been an official update on the progress of the sustainable goals committed 2 years ago.

"I think it's important to act now […] and LUMC has committed to some goals, so we need to walk the talk. If you commit to something, let's do it instead of just talk, write reports and make PowerPoint presentations" – I2

A disconnect has been identified between the bottom and the top of the hospital. All interviewees expressed personal interest and passion in sustainability but felt discouraged to apply their beliefs at work due to the lack of action and support from top management.

"The director thinks it's nice to say like 'Hey, we're a sustainability company'. But not as far as the people who are doing the work would like it to be. […] it's a bit of a greenwash in the LUMC, at the top of the company. Because they like sustainability as long as it doesn't cost any money or will give a profit." – I1

Green Teams at LUMC are self-organized by the employees of each department and consist of activities like weekly meetings, group discussions, initiating sustainable projects, and influencing change through personal green practices in the workplace. Each department's Green Team works independently, and the limited number of joint meetings have all been self-organized. Such decentralized and disconnected operation has been the direct result of LUMC's absence of leadership.

"I think the hospital board could do more about it and be more involved with the Green Team. I'm not sure if they do anything right now. I think a few of them are involved, but they maybe have showed up at a meeting once or something." – I3

Resistance from Employees

To understand LUMC employees' attitude towards its sustainable transition, interviewees were first asked to share their own opinions, followed by what they have

witnessed from their colleagues. All participants reported green behaviors in their personal lives such as recycling, composting, and shopping second-hand, as well as adequate knowledge of sustainability through either academic or personal learning. Two interviewees are in fact members of the Green Team at LUMC's clinical microbiology laboratory department. These results were not surprising considering the participants' enthusiasm in contributing to this thesis which centers around sustainability. On the other hand, however, a general feeling of resistance from some of the colleagues was reported and can be attributed to a couple of reasons. Specifically, in the clinical microbiology labs, I3 explained that most of the employees want a green lab but are not willing to take on any extra work.

"I think they are happy that some people are trying to make the labs a little bit greener as long as they don't have to do something themselves. Like it's good that it's there but I don't want to be part of the green team that's there." – I3

Members of Green Team felt that there is a lack of incentive for others to join, with some colleagues even holding a negative attitude towards sustainability.

"We have a few colleagues; they really don't want to go with the green behavior […] you can't chase those people. Some of them are really annoyed, but that's just two or three people that don't want to hear anything about the Green Team so. I think they don't believe in it, they don't care, or they are just lazy." – I3

Furthermore, participants noticed that it is difficult for people to stay motivated and be consistent with green behaviors, but they also don't want to be constantly reminded. Sustainable practices such as proper waste separation, end-of-the-day shutdowns, and conscious paper usage are easy to follow initially, but require mindfulness to be adopted long-term. An overall mindset shift at LUMC is critical for employees to start viewing green behaviors as the standard practice rather than extra work that they would rather avoid.

"There are 9000 people working here and there's still a big chunk of people who don't separate waste. So it needs to be more on top of the minds of people." – I1

"You can't force them [the colleagues] to turn off their computer every day. So it's a really hard subjects to focus on. We've tried it, but lot of people are like 'I don't want to listen to you.' People are getting really annoyed because you're telling them to turn off their computer, but it's such an easy change to make." – I3

4.2 Barriers to Sustainability

The following section discusses the four main types of barriers identified within LUMC's sustainable transition so far and in the future, namely financial barriers, safety barriers, knowledge & mindset barriers, and other barriers.

Financial Barriers

As previously discussed, due to LUMC's unique financial structure as an academic hospital, cost reduction has been prioritized over sustainable development. Sustainable initiatives that require investments and funding are usually not supported by the hospital, even though environmental benefits are immediately realized, along with financial returns in the long run. On the other hand, external suppliers are mostly profit driven and only view sustainability as an added value. This mutual inaction from both sides of the supply chain has made green procurement at LUMC an impossible challenge. Furthermore, I1 explained that the hospital facility is very outdated and structural upgrades or even a complete reconstruction is required to keep up with the increasing sustainable standards. LUMC's current financial position simply cannot afford such an investment, which means that certain sustainable goals are utterly unattainable, leaving uncertainties for the future.

"For [building] sustainability, you can get a level of gold, silver, bronze, and we're working on that, and we are silver at the moment. And gold is impossible because of the building [itself]. So that's a challenge." – I1

Safety Barriers

Safety barriers within LUMC's sustainable transition are concerned with the hospital's responsibility to ensure patient safety and to comply with the related laws & regulations. An example was given by I1 regarding the lack of waste separation in ORs, resulting in the unnecessary incineration of non-specialized hospital wastes such as recyclable plastic packaging. Around 20 Green Teams along with the waste management department at LUMC have been working on a sustainable initiative to install additional bins for more adequate waste separation in the ORs, but the strict regulations surrounding special hospital waste have stalled their progress.

"I have some initiatives to get extra bins so they can separate the waste, but there are lots of rules or regulations on when to put waste in a regular bin and when it is considered special hospital waste." – I1

The second safety barrier stems from the healthcare industry's overall reliance on disposables. This shift towards single-use medical products made out of plastics started during the United Kingdom BSE outbreak (mad cow disease), due to the inconsistent and inadequate sterilization regulation at the time (F1). Disposables are considered safe and convenient as sterilization is not required for reuse and the risk of infection is eliminated through incineration. However, the negative environmental consequences associated with both the production and incineration of plastics can actually be counterproductive and compromise public health in the long run. Participants believed that hospitals can pursue sustainable alternative practices within the allowed legal realm, such as the off-label reuse of

disposable medical products (F3). According to the Centers for Disease Control and Prevention (CDC)'s guidelines on the reuse of single-use medical devices, hospitals are allowed to do so as long as the reused device complies with "the same regulatory requirements of the device when it was originally manufactured" (CDC, 2016). However, this raises several uncertainties for the hospital such as who is responsible for ensuring the reused devices are up to regulations, and how can they be tested? Healthcare workers are hesitant in attempting such alternative practices despite the sustainable benefits, due to the fear of infections and malpractices (F3). The correlation between patient safety and disposable medical products needs to be reevaluated with environmental and social sustainability taken into consideration. The government has a responsibility in ensuring that healthcare regulations can guide hospitals to confidently pursue sustainability without compromising patient safety.

The last safety barrier is concerned with clinical microbiology laboratories specifically. In a lab setting, patient safety is ensured with the proper handling of potentially infectious samples, so naturally, most modern lab instruments such as pipettes, test tubes, Petri dishes, and microtips are designed as plastic disposables. With an already limited pool of sustainable medical products, LUMC procurement struggled to find instruments that are both of good quality and compatible with the existing equipment at the microbiology labs.

"We could use maybe different pipettes that are more environmentally friendly, but they don't really fit on the machine and that's the kind of stuff that's really hard because you can't make compromises on that." – I3

Knowledge & Mindset Barriers

To measure is to know – a hospital's environmental hotspots can only be identified through rigorous tracking and documenting, and it is a critical step in any organization's

sustainable transition (F1). When asked about LUMC procurement's environmental footprints and microbiology labs' waste generation and energy use, participants reported that the hospital is not actively collecting such data (I1, I2). With an already limited budget available for sustainable developments, LUMC needs to prioritize tackling environmental hotspots and such knowledge barriers can directly hinder the hospital's ability to do so.

Further knowledge barrier has been identified regarding medical practices – I3 feared that some sustainable alternatives are challenging to adopt as the current practices have been in use for so long that they are now standardized across the sector.

"We also have a lot of chemical waste here because we're doing gram staining before putting glasswasher material under the microscope. […] Sometimes I wonder if there's something that can be done to those processes, but I think it's really hard because they have already been using the gram staining for so many years, it's not really easy to change." – I3

Specifically at LUMC's clinical microbiology laboratories, participants expressed that sustainable lab practices are often too expensive, too old fashion, or not up to par in quality (I3). This has been the direct result of the healthcare industry's focus on both cost and operational efficiency, which has led to the shift towards energy-intensive practices such as leaving lab equipment on overnight, and the over-reliance on disposable medical products. Whether sustainable alternatives are truly impractical can only be determined with dedicated research and financial investments, which are both challenging for LUMC to allocate at this time.

Similarly, participants also pointed out that a lot of the infection prevention guidelines hospitals adhere to today are not evidence-based and need to be reevaluated (F1). For example, according to the hand hygiene guideline published by the CDC, healthcare workers should "wear gloves, according to Standard Precautions, when it can be reasonably anticipated that contact with blood or other potentially infectious materials, mucous

membranes, non-intact skin, potentially contaminated skin or contaminated equipment could occur" (CDC, 2021). The guideline is written in vague language and essentially asks healthcare workers to determine the need for gloves based on their own anticipations. Causes for infection are difficult to pinpoint in a hospital's daily operation which has led to doctors and nurses putting on gloves every time they come into contact with a patient. Participants questioned the necessity of such habitual practice considering the negative environmental consequences associated with the production and incineration of medical disposable products (F1). Unfortunately, there is currently no answer due to the lack of more precise guidelines on the appropriate medical settings for glove wearing and the knowledge gap on the effectiveness of sustainable alternative practices such as proper hand washing. Such knowledge barrier is also present in some of the examples mentioned previously, namely LUMC's hesitance in reusing disposable medical instruments and the delay of the sustainable OR waste separation imitative. Without rigorous scientific research and governmental regulations ensuring the safety and feasibility of alternative sustainable practices, hospitals, and healthcare workers are unlikely to make any changes out of the fear of elevated infection risks and potential safety liabilities (F3).

Shifting the focus to LUMC's waste management, both knowledge barriers and mindset barriers have been hindering the hospital's sustainable transition. The example of LUMC's problematic disposable drinking cup usage was brought up by I1 – the advocation for all employees to bring their own reusable cups to work was met with pushback because of the convenience disposable cups provided. As a compromise, the logistics department implemented a sustainable initiative that switched the hospital's disposable cups to cup-to-paper cups which are currently the only cups that can be recycled as paper. However, employees continued to discard them into the regular waste bins due to the lack of knowledge of the new cups' recyclability (I1).

"We do the cup-to-paper cups which are the only cups you can recycle as paper. And they just throw it into regular waste bins. Yeah, so let's stop with the cups because the recycle process doesn't work. Not because they don't want to. But they think, hey, it's regular waste." – I1

Such incorrect waste separation practices can be found all around LUMC. The waste management department has established partnerships with external recycling companies to collect large containers of plastic waste from the hospital (approximately 6000 kilos per container) (I1). When employees improperly discard "dirty" plastic containing food or liquids into the recycling bins even if it's a small amount, the recycling companies would refuse the entire batch. I1 explained that most of the hospital employees are unaware that thousands of kilos of perfectly recyclable plastics are being incinerated due to their incorrect waste separation practices.

"Really important plastics are separated, and we collect them. But if people put really dirty plastic in there, it's a bit of food or whatever […] they [the recycling companies] say sorry, we cannot use it, let's burn it. And people aren't really aware of it." – I1

Other Barriers

Two additional barriers have been identified for LUMC's sustainable transition. The first one is concerned with the global healthcare supply chain disruptions caused by adverse events such as the Covid-19 pandemic and the Ukraine-Russia war (F4). I2 explained that LUMC's procurement department uses the Kraljic matrix in the selection of external suppliers. The Kraljic matrix (see Figure 3) allows companies to "identify areas of opportunity or vulnerability, assess supply risks, and derive basic strategic thrusts" in the purchase of a specific product (Kraljic, 1983). Recalling the start of the Covid-19 pandemic, I2 used the sudden increase in demand for face masks by the public and the subsequent

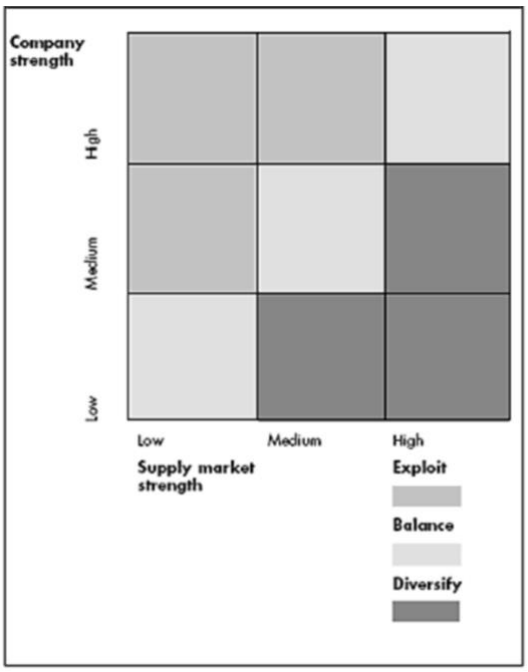
unavailability due to production disruptions in China as an example to illustrate the highly strategic operational challenges faced by LUMC's procurement department.

"Masks went from a low interest, low-cost product and all of a sudden it was high interest, and it was a continuity risk for the business. There were some changes in the risk matrix where we plot our suppliers in the matrix, is it high risk or low risk? Where is it coming from? So we had to change our thinking a bit depends on the availability in supply chain." – I2

The occurrence of such adverse events is unpredictable and as climate change keeps on worsening, supply chain disruptions will only happen more frequently. As a result, sustainable considerations will be put on the back burner as hospitals struggle to ensure an adequate supply of essential medical products like Personal Protective Equipment (PPE). In the long term, this reinforcing feedback loop will only lead to irreversible damage to both public health and the environment.

Figure 3

The Kraljic Purchasing Portfolio Matrix



Note. Adapted from "Purchasing Must Become Supply Management," by P. Kraljic, 1983, *Harvard Business Review*, (https://hbr.org/1983/09/purchasing-must-become-supply-management).

The second barrier is concerned with sustainable medical equipment and instruments' compatibility and quality. Participants reported past failed attempts of switching to more sustainable products due to compatibility and quality issues.

"I found another package and the company presented it like it was the best pipette tips you can have. It's made with plastic that's easy to recycle. We tried them but they didn't fit our pipettes so that was a big disappointment." – I3

"The two-color agar plates can be a good idea if it doesn't affect the quality of the test. I think that's something we can look into but it has to be validated, […] right now the system is programed to make the culture for the whole plate. So if it's not compatible with the machine then that's an issue." – I3

In the clinical microbiology laboratory setting, some equipment such as the PCR machine is used in conjunction with instruments of precise dimensions and qualities. While medical equipment is generally standardized across the industry and requires a large sum of investment, there are way more options for consumables, and are often purchased in batches. Both I1 and I3 emphasized the importance of compatibility and quality when selecting consumable suppliers for the labs at LUMC. I2 pointed out that medical equipment manufacturers are currently producing uniquely designed consumables in order to push hospitals into a package deal purchase, in turn maximizing their profits. Such sales strategies further hinder LUMC's pursuit of sustainable procurement by limiting the hospital's ability to choose from more sustainable suppliers altogether.

"For most of the machines, especially for the molecular biology, the manufacturer of the machines is making special tips that are only for that machine and we can't use other pipettes." – I3

4.3 Stakeholder Strategies for Sustainable Hospital & Laboratory

With the identification of LUMC sustainable transition's barriers and challenges, areas of improvement and opportunities arose as well. Data findings emerged on the common theme of stakeholder collaboration and have been categorized into individual responsibilities, organizational efforts, and industry collaboration. Specific strategies for sustainable transition are outlined to address the identified barriers and ultimately answer the research question of this thesis, with the support of relevant literature.

Individual Responsibilities

On an individual level, every single person at LUMC (staff, healthcare workers, management, and patients) is capable of green behaviors such as proper waste separation, less paper use, low emission traveling, mindful energy, and water consumption, etc. (I3, I4). Participants pointed out that common sustainable practices people already implement in their personal lives are easier to carry over into the workplace (I3). Younger professionals at LUMC are really interested in sustainability, whereas older professionals generally have less awareness of the topic (I1). The knowledge & mindset barrier can thus be overcome with an intentional shift on an individual level to start incorporating sustainability considerations into every action (Borges de Oliveira & de Oliveira, 2022; Kaplan et al., 2012). Participants believed that this can be achieved with increased awareness throughout LUMC and by thinking big but starting small with sustainable initiatives (F1).

Specifically in clinical microbiology laboratories, staff training should be put in place to raise awareness amongst employees and in turn engage them in identifying environmental hotspots and suggesting opportunities for improvements. (Lopez & Badrick, 2012). Lopez & Badrick (2012) further suggested the appointment of a laboratory environmental manager that oversees the lab's continuous efforts toward sustainable initiatives. This facilitator role can also be taken on by a team which could lead to the rest of the lab's increased involvement in problem-solving and motivation for implementing sustainable practices (Lopez & Badrick, 2012; Lopez et al., 2017; Molero et al., 2021). I3 as a Green Team member of LUMC's clinical microbiology laboratories expressed hope that by actively doing green behaviors at work and making sustainability more visible, changes can be inspired amongst colleagues with less awareness.

"We are trying, like most green team members when we are closing down the lab, I'm like, OK, I'm going to turn off some the computer for some of the people because they forgot." – I3

Organizational Efforts

The essential starting point of organizational efforts has been identified as a collective mindset change at LUMC to include sustainability as a core mission of the hospital (I2).

"I think as a company or as a hospital you need to change the mindset and said OK this as a company or a hospital is what we want and then everybody should follow this mindset." – I2

LUMC has attempted to reduce energy use by shutting down ventilation systems at 6 PM but ended up extending it to 8 PM because employees were working late and complained to the hospital board (F5). Participants believed that the hospital board needs to be firm on its stands on sustainable transition to avoid such pushbacks (F5). It is also evident that a cultural shift on an organizational level and a mindset change on an individual level are interdependent, and they must be implemented synchronously to ensure success (Borges de Oliveira & de

Oliveira, 2022; Kaplan et al., 2012). Furthermore, participants believed that prioritizing sustainability can also lead to more budgets allocated to sustainable developments, aiding the current financial barriers at LUMC investigated previously (I1, I2).

As mentioned before, all the Green Teams at LUMC are self-organized by each department and work independently. As a member of the microbiology lab Green Team, I3 believed that collaboration amongst all the teams can lead to mutual assistance and knowledge sharing. The leadership to facilitate such joint efforts falls on LUMC's board and management (I1, F1). In fact, Lopez & Badrick (2012) argued that sustainable transition at laboratories "will only succeed with the support of the senior management of the organisation and with a public commitment to devote time and resources to this endeavour" (p. 1559). Past literature has recommended the implementation of EMS or an environmental policy integrating sustainability into all the lab's activities (Lopez & Badrick, 2012; Yusuf et al., 2022). LUMC's clinical microbiology currently does not have such concrete planning and the efforts toward sustainable initiatives have mostly come from members of the Green Team. Scholars identified the three keys to success for such management systems as long-term senior management support, engaging the lab workforce through public commitment to sustainability, and resource & impact monitoring (Lopez & Badrick; Yusuf et al., 2022). As one of the knowledge barriers previously identified, LUMC's lack of environmental footprint tracking is hindering the laboratories' ability to set up such environmental policy targeting specific hotspots.

On the other hand, participants also pointed out the importance of bottom-up identification of sustainable opportunities, especially for the transition toward sustainable procurement at LUMC. I3 and I4 both agreed that although the hospital is responsible for purchasing products used by the entire hospital, microbiology laboratories must select the suppliers for special lab instruments; thus lab employees should provide the best judgment on

both quality and sustainability considerations for procurement. Green teams can take the lead on identifying and implementing sustainable initiatives, which would hopefully be carried over to all the employees throughout LUMC (I3).

"Things like writing down results on paper or computer, I think that's our responsibility as Green Team to think about and I think it's for the doctors here who has responsibility about the lab that everything is quality, the quality of our tests, and what we do is good. I think they [LUMC board] are responsible at the end process, but we can make these suggestions." – I3

Rodríguez et al. (2021) classified it as the top-down versus bottom-up paths to sustainable development, emphasizing the importance of hospital management's leadership in fostering employee participation. Ultimately, the success of sustainable transition at LUMC's microbiology laboratories depends largely on the organizational efforts made by the hospital and all its stakeholders as a whole.

Industry Collaboration

Widening the scope even more, sustainable transition at LUMC requires not only internal efforts but also collaboration throughout the entire healthcare industry. Firstly, participants noted the increasing demand by hospitals for proactive sustainable initiatives from external partners (I2, F3). At LUMC, there have already been some positive examples such as the partnership with waste management company PreZero. I1 explained that the hospital has set out some recycling goals with PreZero and prices can only be raised when targets are met. By making it a business case with financial incentives, LUMC was happy to be on board with the initiative. This finding was not surprising as Lopez et al. (2017) suggested that initiatives with the potential for long-term cost savings are more likely to gain senior management support. Another example entails a joint exposition at LUMC presented by the waste management department and PreZero, showcasing various new products made

from the hospital's recycled wastes. I1 believed that employees at the hospital should be aware of the positive outcomes of their waste separation efforts which would hopefully lead to increased willingness and motivation for sustainable practices.

"We have together with PreZero made an exposition of things that are remade and reused with our waste. Like plastic cups we made, the chairs we made, so if we do it really well, these are the things we can make. So we hope that people know it's really useful too." – I1

However as previously mentioned, most of LUMC's external suppliers still view sustainability as an added value to increase profits which can be attributed to the lack of knowledge on circular product designs. An example was brought up concerning the absence of take-back programs for product packaging which are mostly made with plastics and perfectly reusable and recyclable (I3, I4). However, the use of tape and stickers on packaging greatly reduces the recyclability of polypropylene (F1). More evidence-based research on current medical practices and designs is desperately needed to overcome such knowledge barrier. In the example of glove use, healthcare professionals at Great Ormond Street Hospital (GOSH) launched the "Gloves Are Off" campaign to encourage the reduction of unnecessary non-sterile glove use. By asking healthcare workers to practice risk assessing every time they use gloves and increasing awareness of sustainability, positive outcomes were observed including healthier skin for employees and 21 tons of plastic reduction – all with no adverse rise in infections (Great Ormond Street Hospital, 2019). Such initiatives are a great starting point; however, further research needs to be conducted more systematically across the healthcare industry. Participants pointed out that a broader perspective is needed for medical laws and regulations to incorporate sustainability considerations (F3). Circular practices concerning both medical product design and waste management are currently stalled due to the identified safety barrier. For example, although 20% of the medical waste in the Netherlands can no longer be incinerated locally, it is currently illegal for companies to

transport, receive, and reuse contaminated medical materials (F2). Van Straten Medical is the only company in the Netherlands that is allowed to reuse and reprocess discarded medical products through urban mining and a special permit had to be requested from the government for that purpose (F2). The founder – as a contributor to the study van Straten et al. (2021) – found that both financial and environmental benefits were gained through refurbishing instrument waste and returning usable products to hospitals for reuse. It is evident that the government is currently taking a passive approach to sustainable healthcare and more initiatives are needed to help guide hospitals through this transition without elevating safety concerns. Especially in the clinical microbiology laboratory setting, Molero et al. (2021) argued that interdisciplinary research is critical in supporting the development of sustainable integrated care models.

Lastly, I4 pointed out that all healthcare organizations need to join forces in advocating for sustainable developments in the sector. The current mismatch between hospitals' demand for sustainable advancements in the areas of procurement, healthcare pathways, and circularity, along with the inaction of external stakeholders – can both be solved with collective advocacy.

"This [sustainable procurement] is only possible when a lot of hospitals, labs and other caretakers can work together to convince the suppliers to make that move." – I4

5. Discussion

This chapter aims to address this thesis's theoretical and practical contributions while answering the research question "how can clinical microbiology laboratories move towards a sustainable future?" Then moves on to address the limitations encountered during research, as well as some recommendations for future studies on the topic of sustainable hospitals and laboratories.

5.1 Theoretical & Practical Contributions

This thesis set out to address the multiple knowledge gaps identified by past literature and in doing so important theoretical and practical contributions were made.

Theoretically, this study contributes to the extremely limited pool of research on sustainability in the clinical microbiology laboratory setting and it is amongst the first to use a stakeholder view in providing sustainable development strategies. As it is a case study done at a working hospital, the findings could be valuable in understanding the challenges and opportunities of sustainable laboratories for both academics and stakeholders of the healthcare industry. Various sustainable strategies identified in this study corresponded with those mentioned in previous literature, further proving their feasibility and thus increasing the applicability of this thesis. New barriers and opportunities emerged from this research, namely difficulties in sustainable procurement due to lab instrument suppliers' monopoly through unique compatibility and increasing sustainable awareness by making initiatives visible. These findings contribute to the further research of sustainable laboratories.

Additionally, through a stakeholder view, the sustainable transition was envisioned in three dimensions – individual, organizational, and sectoral; thus the findings contribute to the knowledge gaps identified in both sustainable hospitals and the healthcare industry as a whole. This thesis expands the field of research on sustainable laboratories with the inclusion

of these broader perspectives as the current literature focused more on practical changes that can be made at the laboratories specifically (Lopez & Badrick, 2012; Lopez et al., 2017; Molero et al., 2021; Yusuf et al., 2022). Lastly, this research contributes to the development of modern stakeholder theory by applying it to the sustainable transition at clinical microbiology laboratories. Existing literature adopting the stakeholder view in healthcare mostly focuses on the management of stakeholders from corporational and ethical perspectives (Buthion, 2011; Elms et al., 2002; Werhane, 2000). Studies concerning sustainability in healthcare are severely limited, and to the best of the researcher's knowledge, this is the first research to do so in a laboratory setting (Khosravi & Izbirak, 2019; Martin et al., 2022; Pereno & Eriksson, 2020).

Practically, this thesis contributes to the lack of sustainable efforts in the clinical microbiology setting. By taking on a case study approach with LUMC as the subject, the sustainable strategies outlined in the findings chapter can serve as a guideline to implement real changes at the hospital. There are several other UMCs in the Netherlands and many of them participated in the Thesis Lab, indicating their interests and ambitions toward sustainable development. This study took into consideration the unique financial and organizational structure of an academic hospital; thus the findings could serve as directions for sustainable transition at other UMCs and their clinical microbiology laboratories as well. Furthermore, the final activity of the Thesis Lab consisted of a presentation to Medical Delta, LUMC, and invited scholars involved or interested in this project and the research results. If not inspiring change at other hospitals, this thesis has at least raised awareness of sustainability in hospitals and laboratories amongst the attended guests. The true power of stakeholder collaboration lies in the number of forces working together.

Widening the scope beyond the healthcare industry, various barriers for organizations to achieve sustainable transition have been identified. Financial barriers are faced by almost

all sectors when it comes to sustainable considerations. The global awareness of sustainability and its importance is still severely limited; this is evident in nations' failure in measuring up to the sustainable goals made in the Paris Agreement. In fact, the mindset and culture change needs to happen on a global level to achieve overarching sustainable developments such as a complete shift towards green energy sources and city planning with sustainability considerations. Safety barriers can be present in other industries such as food, construction, and manufacturing. Thus the findings of this thesis practically contribute to the understanding of sustainable barriers and how to overcome them with stakeholder strategies for more than just one type of organization.

5.2 Limitations & Recommendations for Future Research

The first limitation of this thesis stems from the limited amount of data collected. Focus groups were planned initially, however, due to the pandemic, employee availability at LUMC's clinical microbiology was extremely limited. It was eventually not feasible to conduct a focus group which the researcher believes could have brought about more perspectives. Furthermore, this thesis was conducted at an academic hospital which could make the findings less applicable to traditional hospitals. The Netherlands is also very advanced globally on sustainable developments, suggestions such as sustainable procurement and low-emission traveling could be much harder to implement in other nations without similar recourses.

A couple of recommendations can then be made for future research. Most of the sustainable efforts toward sustainable laboratories are currently presented as certifications, frameworks, and practice guides. There's a need to document the successful examples of their implementation in an academic research form to continue filling in the knowledge gap on sustainability in clinical microbiology laboratories. This would require research with

longevity to actually attempt sustainable transition at labs and wait to see the results while recording the process in detail. More importantly, the healthcare industry needs to take on a more proactive approach to sustainable development and investigate care pathways that actively promote public health instead of passively dealing with diseases and crises. Climate change is only getting worse; in the end, the healthcare industry will have to be on the front line; medical workers will have to sacrifice their own safety; the environment will have to continue suffering. Sustainability is not an added value; it is a must if we want future generations to enjoy a quality life. We must act now.

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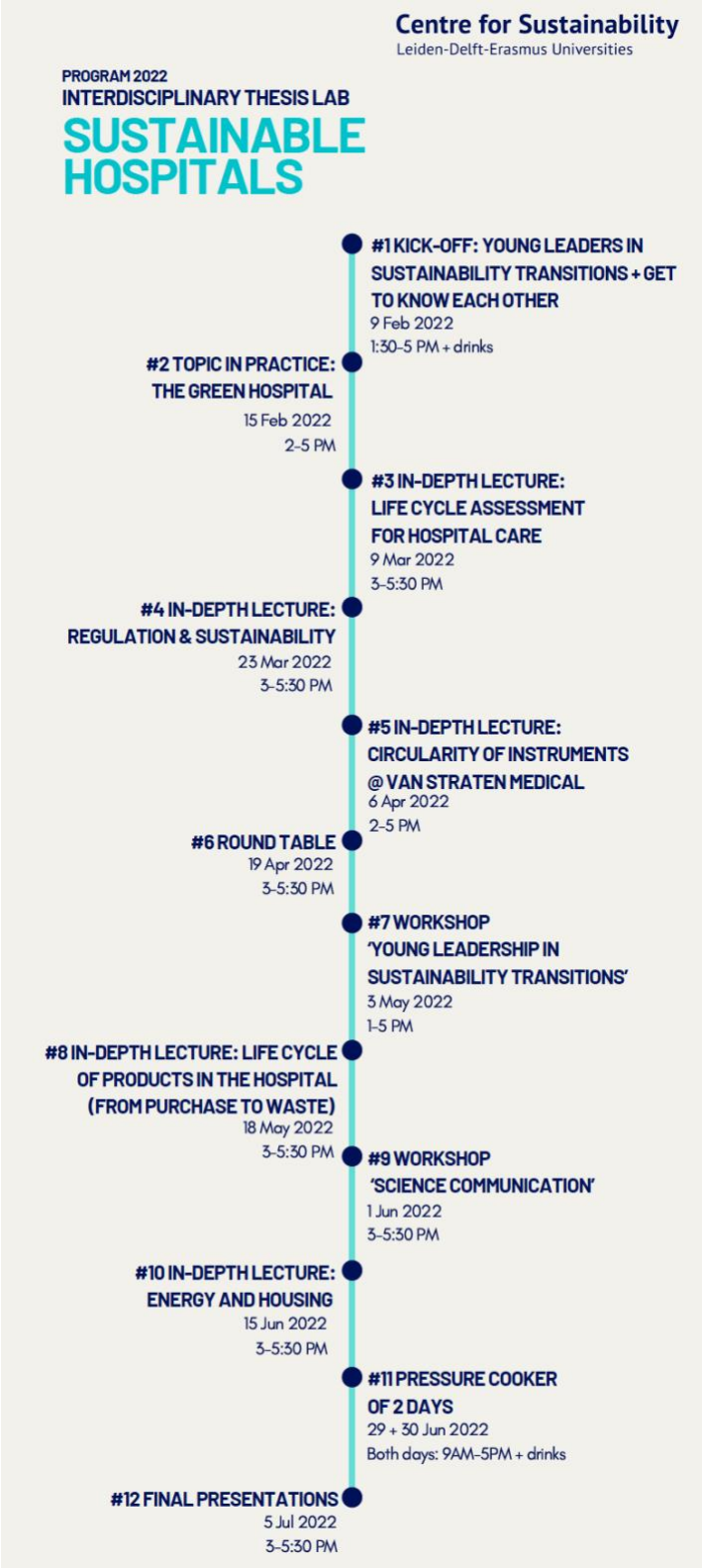
Appendices

Appendix A – List of Interdisciplinary Thesis Lab Activities



Appendix B – An Overview of Fieldnotes with Codes

Codes	Date	Event	Number of Pages
F1	February 15th, 2022	Topic in practice: The green Hospital	3
F2	April 6th, 2022	In depth lecture: Circularity of instruments	1
F3	April 19th, 2022	Round table	1
F4	May 18th, 2022	In depth lecture: Life cycle of products in the hospital (from purchase to waste)	2
F5	June 15th, 2022	In depth lecture: Energy and housing	1

Appendix C – Interview Guides for SSI

Confidentiality Statement:

To facilitate notetaking, I would like to record the audio of this interview. For your information, only I will have direct access to the recording which will be eventually destroyed after transcribing. All your information will be held confidential, and the reader will not be able to trace back any specific interviewee from my thesis. I do not intend to inflict any harm to any organization or person with this project.

For Microbiology Laboratory Employee:

Section	Topics	Sub questions
Introduction questions	1. Personal background	- role at the lab? - work experience?
Theme questions	2. Sustainability	- what is your understanding?
	3. Current hotspots	- energy waste? - most discarded instrument?
	4. Current green behaviors	- recycling? What's going well? What's not? - any other green initiatives?
	5. Attitude towards Sustainability	- how do you feel personally? - how do you think your colleagues feel?
	6. Supplier (when applicable)	- who are the suppliers for medical instruments? - how were they chosen? What qualities are you looking for? (Price, quality…) - do you know if they have sustainable ambitions? - how important is that for you?
	7. Ideas for opportunities	- what can be done about the hotspots? - who are responsible? - who can help? - when can that happen?
	8. Ideas for challenges	- what can be some challenges transitioning to green hospital?
Closing questions	9. Closing	- is there anything else you'd like to add? - thank you & let's keep in touch for potential further questions

For Waste Management Department Employee:

Section	Topics	Sub questions
Introduction questions	1. Personal background	- role at the department? - work experience?
Theme questions	2. Sustainability	- what is your understanding? - are there any sus practices at the department currently? - other green initiatives?
	3. Attitude towards Sustainability	- how do you feel personally? - how do you think your colleagues feel?
	4. Main activities	- what does the department do? - how many employees?
	5. Work environment	- is it healthy? - is it very labor intensive? - any health risks or concerns? - fair pay/hours?
	6. Current partnerships	- are there any current partnerships? Who? - what are the advantages? Disadvantages? - who get to pick the partners? - what are some valued attributes while picking? (Price, service quality…)
	7. Clinical microbiology labs	- how much waste come from the labs on average? - what are they mostly? (Recyclable? Hazardous?)
	8. Ideas for opportunities	- what do you think can be done about the waste? - who are responsible? - who can help?
	9. Ideas for challenges	- what can be some challenges transitioning to green hospital?
Closing questions	10. Closing	- is there anything else you'd like to add? - thank you & let's keep in touch for potential further questions

For Procurement Department Employee:

Section	Topics	Sub questions
Introduction questions	1. Personal background	- role at the department? - work experience?
Theme questions	2. Sustainability	- what is your understanding? - personal green behavior?

	3. Main activities	- what does the department do? - does the department calculate the environmental footprint of the purchases
	4. Current partnerships	- who are the biggest suppliers? - what are valued when choosing suppliers? - is it important for suppliers to have sustainability ambitions? - do doctors have a say in the final selection? - do doctors demand for sustainable products? - is there transparency in the suppliers? - are there any take back program or circular initiative from suppliers
	5. Ideas for opportunities	- who are responsible for meeting the hospital's goals to reduce waste?
	6. Ideas for challenges	- what can be some challenges transitioning to green hospital?
Closing questions	7. Closing	- is there anything else you'd like to add? - thank you & let's keep in touch for potential further questions

Appendix D – An Overview of Interview Transcripts with Codes

Codes	Interviewee Department	Role at Department	Interview Duration	Number of Transcript Pages
I1	Logistics, Waste Management	Manager	51:27	13
I2	Facility Management, Procurement	Contract and Supplier Manager	35:34	4
I3	Medical Microbiology	Lab Technician	46:30	4
I4	Medical Microbiology	Lab Technician	28:25	2