Interdisciplinary Thesis Lab 2023-2024:

medical delta

we add

Sustainable Healthcare

Universiteit Leiden

TU Delft

Erasmus University Rotterdam

Colofon

This document includes the thesis assignments for the thesis lab ‘Sustainable Healthcare’.

LDE Centre for Sustainability

Version 1.0
The 25th of september 2023

Centre for Sustainability
Leiden-Delft-Erasmus Universities

Thesis assignments

Introduction

No more talking: action is needed

The average life expectancy in Europe continues to rise. Due to aging and the impacts of climate change on human health, the demand for care will increase in the coming years, as will the costs. Healthcare carries an important responsibility in maintaining the health of people, but also in ensuring a healthy environment for people to live in. Seven percent of the total carbon footprint of the Netherlands is related to the healthcare sector. The operating room alone is responsible for approximately 20-30% of the hospital waste and pollution is increasing with the development of new technologies and materials. Besides the 81 hospitals, there are over a thousand organisations operation in care: elderly homes, ambulant, psychiatric and handicapped facilities. Energy use and waste production is large and overlooked contribution to the climate crisis.

All this requires a drastic transition of healthcare. Technological innovations will play a crucial role in this transition, but it is also of great importance that technology fits healthcare practice. This is only possible if scientists from different disciplines work together - with each other and with end users.

To make the whole health care sector more sustainable, a drastic transition is needed.

Are you up to the challenge?

Last year, we challenged students to identify what steps can be taken today to make a hospital more environmentally sustainable. This year, we are pushing the challenge further. We are broadening our scope to the whole health care sector, looking beyond hospital walls. Knowing the steps that can be taken today, why are these not taken? What are the barriers, risks but also the opportunities in sustainable health care? We challenge you to write a call to action for hospital boards. What actions can hospital boards take to start their journey towards sustainable healthcare?

The challenge: What steps can be taken today to make healthcare more environmentally sustainable for our future?

Moving towards environmentally sustainable healthcare requires a complex transition from multiple stakeholders. Within health care organisations, multiple departments with each their specialties, tasks, visions and needs work hard to provide high quality healthcare. Stakeholders outside health care organisations, such as the manufacturing industry, provide equipment, devices and medicines. Patient safety is key and choices that subtract from the well-being of patients and staff are out of the question.

The Thesis Lab on Sustainable Healthcare gives you the opportunity as a master student to explore sustainability challenges with the guidance of experts in the field. We provide in-depth lectures and site-visits to deepen your knowledge and perspective. Your collaboration with peers will speed up the learning process. The aim of this thesis lab is to recommend solutions for relevant stakeholders. Therefore, your work will lead to real impact on a more sustainable healthcare sector."

Interested in joining the Thesis Lab?

Get in touch with or submit your application online
Registration opens on the 27th of September 2023

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For more information on enrolment and selection procedure, **click here.**

Partners

LDE Centre for Sustainability and Medical Delta are joining forces again in their mission to make healthcare more sustainable.

Medical Delta is an interdisciplinary collaboration of more than 360 researchers from Erasmus University, Erasmus MC, TU Delft, LUMC, Leiden University and four universities of applied sciences in the province of Zuid-Holland. Together with companies, healthcare organizations and governments, they work on technological solutions for sustainable healthcare. In doing so, Medical Delta gives an enormous boost to the life sciences & health sector in the Zuid-Holland region and beyond. See: https://www.medicaldelta.nl/en

#01 SH Green Calculator

How can we measure sustainable impact in the Intensive Care Unit? Development of the ICU green calculator

Problem statement:

The Intensive Care (IC) is one of the most polluting departments of a hospital. In the name of patient safety and hygiene measures, many materials are packaged and/or wrapped. Both packages and materials and instruments are frequently disposable, creating a lot of waste. The Green IC ('de Groene IC') network in the Netherlands was started by medical professionals working at IC units (ICUs), such as intensivists and IC nurses. Their aim is to make ICUs sustainable. To do this several sustainable interventions have been developed. The network wants to make these interventions available to all ICUs in the Netherlands. Therefore, it is about to launch its website with sustainable interventions. However, the Green IC does not have specific information about the environmental impact of these interventions. Information about the impact is needed to create awareness amongst IC staff and hospital boards. Furthermore, it can serve as a "green calculator" that ICUs can use to calculate their impact and compare this with other ICUs.

Research question(s):

- **What is the environmental impact (CO_2 footprint) of specific ICU interventions?**
- **Is it possible to develop a green calculator that can be used by ICUs to measure, show and track their environmental impact? Examples are: gloves, gowns, infusion bags etc.**

Expected type of work

Life cycle assessment and use of existing data in combination with interviews.

Commissioner details

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#02 SH Cleanup Contrast GBCA in Hospital Waste Water Chain

The Contrast Cleanup: Assessment of the level of gadolinium-based contrast agents (GBCA) in the university/hospital wastewater chain

Problem statement:

The number of CT and MRI scans increase. This also increases the use of contrast media given to patients necessary to perform the scans. Contrast media, such as GBCA, are excreted in patients' urine and end up in the wastewater stream. Although there is more focus on the adverse effects of contrast media on the environment (especially in waste-, surface-, river- and drinking water), there is only limited data available on the actual levels of GBCA at various points of the wastewater chain of Leiden university and its teaching hospital, LUMC, which have a common sewage water collection system.

Current data, like the RIWA (association of River Water companies) report of 2013, is often outdated or investigate contrast media that have been banned by the European Medicines Agency. With the renewed focus on the environment comes a need for new, accurate data. The results for waste water could be matched to the results for river and drinking water for a complete evaluation of the level of GBCA in the water chain.

More than 50% of the administered GBCA will be excreted in urine in normal households, flowing to a variety of wastewater treatment plants. The measures to reduce GBCA contamination taken by the Leiden University and the LUMC may serve as model to guide reduction of water contamination by all households.

Research question(s):

- **To determine the level of GBCA in the waste waters of from a large university and hospital**
- **How the level of GBCA in water changes on route from the university and its hospital to the waste water treatment plant (WWTP/AWZI) and eventually to the North Sea.**

Other the research possibilities:

- To determine the level of GBCA in surface and river waters in a wide area around a the LUMC (in ditches, small streams, Leiden's canals, Oude Rijn and Korte Vliet rivers, De Kaag and Valkenburg and Braassemermeer lakes).
- How the level of GBCA in surface/river waters will be influenced by/correlate with the level of GBCA in wastewater.
- The influence of GBCA in surface or coastal water or water flora and fauna

Expected type of work

Desk research phase:

- Systematic survey on literature on GBCA in waste water and surface water around hospital
- Analysis where in the hospital waste water chain selective water sampling could take place, to discriminate waste water flows from separate parts of the hospital/university

Analytical phase:

- Sampling and analysis of GBCA levels in wastewater at several places in the university and hospital collection puts on route to the treatment plant, and in the affluent and effluent streams of the wastewater treatment plant Leiden Noord (via our collaboration with RIWA Rijn).This research project is carried out in collaboration with the Dutch network 'de Groene OK' and the RIVM. Some basic knowledge about the use of pharmaceutical drugs is preferable.

Commissioner details

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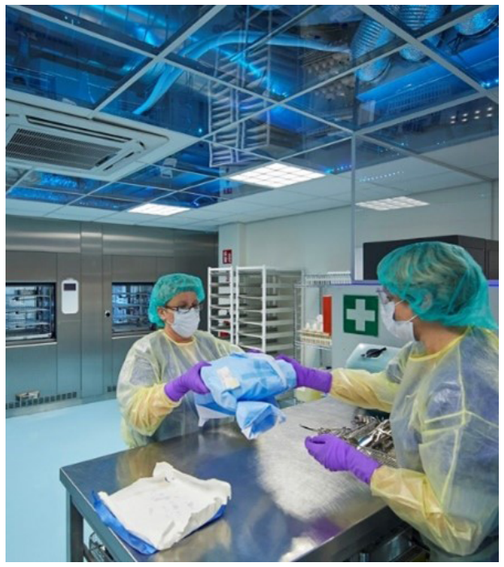
#03 SH Incinerate or Innovate

Incinerate or innovate? Which hospital waste disposal is actually most sustainable?

Problem statement:
Hospitals are waste production organizations and responsible for 8% of the total CO2 emissions.

During the last decades a growing number of disposables were introduced. Developments such as the transformation of reusable medical devices to disposable devices, but also new techniques and robotic surgery introduced even more disposables.

A Fieldlab was set-up in De Meern-Utrecht in co-operation with Medical Delta, TU Delft, LUMC, participating hospitals, Gemeente Utrecht and GreenCycl. A recycle/production line was built in this Fieldlab where medical waste such as blue wrapping paper, PET and PE packaging, instruments, are melted and reprocessed to raw material. This raw material is used to produce new medical devices at the same location.



Currently however, there is no clear vision regarding the amount of CO2 emissions between medical waste collected from the hospital and reprocessed to new raw materials and new products in De Meern, as compared to the medical waste which is burned in the incineration oven at Zavin in Dordrecht.

Research question(s):
What is the difference in CO2 emissions for the following two medical waste stream flows:
- **1.) Collecting medical plastic waste from hospitals in the Netherlands, transport to the Fieldlab in De Meern where it is reprocessed to new raw material and to new medical products.**
- **2.) Collecting medical waste from hospital in the Netherlands, transport to Zavin in Dordrecht and incinerate the waste.**

Subquestion: To what extent can this be extrapolated to other waste streams and can you therefore answer the more general question of reducing waste in society?

Expected type of work
A life cycle assessment or equivalent method to calculate climate change impact in combination with using data from ecoinvent. Interviews with participants in LUMC, HMC and staff of GreenCycl to research what the mean waste streams are and how the work flows need to be changed for separating and collecting waste. Use the data from ecoinvent and relate this to the melting process and energy in the Fieldlab.

Remarks
Full support is available, both for setting-up an LCA method or an alternative database method as well as for retrieving the data. Furthermore, accessibility in a network of hospitals and healthcare professionals is available to visit or to interview.

The facilities of Van Straten Medical are situated at Rijnzathe 2 and Molensteijn 1c in De Meern - Utrecht, directly situated by the highways A12 and A2. Public transportation with bus stops in front of the facilities. A Central Sterilization Department as well as an instrument manufacturing and a recycle-production FieldLab are situated on the same premises.

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#04 SH Impact of disposable medical instruments

Disposable versus reusable surgical Instruments: what is the real difference in environmental impact?

Problem statement:
The health care sector is responsible for 8% of the Dutch CO2 emissions. The hunger for plastics and steel grew as products had to be manufactured in increasing volumes. As the world population is growing and so is the number of patients. This phenomenon is further supported by the introduction of single-use medical products, the so-called disposables. Medical instruments, which were mostly reusable in the previous century, became more complicated and many were converted from reusable to disposable. The waste production of hospitals has increased significantly, although there are many methods for increasing the life span of medical instruments, e.g. by using reusable instead of disposable instruments. This is done by implementing an active program for instrument maintenance, repair and refurbishment. Still, many hospitals prefer to use disposable instruments.

There is a major task to map the difference in CO2 emissions between disposable and reusable instruments in order for hospital staff to visualize the difference between the use of these two types of instruments. Sustainability is not incorporated in purchasing decisions. Because there is still insufficient data on this topic and because the social relevance is very high, it is very valuable to investigate the difference in CO2 emissions.

Research question(s):
The aim is to assess and compare the impact on climate change of disposable surgical instruments versus reusable instruments (i.e. chose 1 or 2 instruments such as a needle holder, tweezer, and scissors) and the impact of repair and maintenance of these instruments?
The research sub questions are:
- 1.) What is the impact on CO2 emissions of reusable instruments versus disposable instruments, used only once?

- 2.) What is the impact on climate change when reusable instruments are repaired instead of disposed and replaced with a new instrument?

- **3.)** What are the financial differences of reusable versus disposable instruments in a time frame of ten years? And the financial impact of product life extension by repair and maintenance?

Expected type of work
A life cycle assessment (LCA) in combination with using data from the ecoinvent database and interviews (50/50%) with instrument technicians, staff central sterilisation department and medical specialist (all present at Van Straten Medical/CSA services in De Meern). Cost calculations of prices of disposable, new versus repair and maintenance prices to calculate cost differences between the different flows. All data available in De Meern, to be retrieved via interviews and ERP system.

Remarks
Full support is available, both for setting-up an LCA method or an alternative database method as well as for retrieving the data. Furthermore, accessibility in a network of hospitals and healthcare professionals is available to visit or to interview.

The facilities of Van Straten Medical are situated at Rijnzathe 2 and Molensteijn 1c in De Meern - Utrecht, directly situated by the highways A12 and A2. Public transportation with bus stops in front of the facilities. A Central Sterilization Department as well as an instrument manufacturing and a recycle-production FieldLab are situated on the same premises.

Commissioner details

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#05 SH Greening your PET

Greening the process, the most sustainable PET/CT material flows

Problem statement:
At the Nuclear medicine department of Alrijne Hospital several diagnostic imaging modalities are used as: Positron Emission Tomography combined with CT (PET/CT) and Single Photon Emission Computed Tomography combined with CT (SPECT/CT) and Molecular Breast Imaging (MBI). Nuclear Medicine is a specialized field that uses various very small amounts of radioactive materials, or radiopharmaceuticals, to examine organ function and structure.
The Nuclear Medicine department at Alrijne collaborates with referring departments such as: orthopaedics, oncology, neurology and cardiology.

Optimizing (patient) workflows and introducing new technologies in clinical practise is of importance. However, up to now sustainability is not yet integrated in the (clinical) decision making. Furthermore, it is challenging to incorporate sustainability since little research has been done in this field. Sustainability research in other healthcare fields has shown that there are several ways to lower environmental impact.

One approach to reducing environmental impact might be switching from single-use to reusable healthcare products or look for more sustainable alternatives and optimizing the material flow. Various materials are needed to perform PET/CT scans and most of it is not reusable, resulting in waste and high costs. Replacing single-use products with reusable or more sustainable alternatives may reduce the environmental impact of healthcare. Furthermore, to reduce the environmental impact one must also look at optimizing material usage. The aim of this research is to optimize the material usage of various PET/CT procedures at the nuclear medicine department and where possible, look for more sustainable alternatives.

Research question(s):
What is the optimal material flow of PET/CT procedures and how we can implement the most sustainable solutions in clinical practise?

Other the research possibilities:
- Material flow analysis of PET/CT procedures at the nuclear medicine department
    a. What materials are used in clinical practise and what can be optimized?
    b. What are the alternative sustainable materials and what are the barriers to use these materials (including costs, infection prevention, logistics, etc.)?
    c. How can we overcome these barriers?
- Which materials are used for various radioactive tracers as F18-FDG, F18-PSMA, F18-NaF etc.?
- Which (quantifiable) parameters should be considered to assess the sustainability of PET/CT materials?
- How can we apply sustainable (quantifiable) parameters in our decision making?
- Deliverable: report on how we can optimize our material usage and an implementation plan on how we can achieve this.

Expected type of work
- Material flow analysis of PET/CT procedures at the nuclear medicine department
- Analysis of different types of materials and their environmental impact
- Report on how we can optimize the material flow and how we can implement the most sustainable solutions

Other remarks
We expect that especially students with a background In economy or business administration and interest In healthcare would fit this project. However, all interested students in this subject are encouraged to creatively and proactively make this project their own and come with suggestions for research directions.

References and available resources
- Sustainability mission and vision of Alrijne hospital
- Project with focus on using reusables instead of disposables
- Sustainability policy Alrijne hospital
- Alrijne is cooperating in a project to develop a database with sustainable healthcare alternatives for disposables

Commissioner details
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#06 SH Power down at Pediatrics

Greening the Electricity consumption at the paediatric intensive care unit: How much power can we save by shutting down equipment?

Problem statement:
The Green Deal to improve environmental sustainability in healthcare aims to ultimately improve the impact of healthcare on climate change. And as children will suffer the most from climate change, paediatric health care should take an important responsibility in achieving this Green Deal. An important contributor to climate change is electricity consumption. Naturally, hospitals consume a lot of electricity, most of which is carbon-fuelled. In the paediatric intensive care unit (PICU), electrical devices such as ventilators, patient monitors, computers, infusion pumps and many more have become indispensable and tend to be switched on continuously, also in absence of a patient. As such, the PICU is highly dependent on electricity, but could paradoxically also be pulling the cart when it comes to a reduction of electricity consumption. Identifying unnecessary electricity consumption is a first step to achieve this.

Research question(s):
How can we reduce electricity consumption in the PICU?

Sub questions:
- 1.) How much electricity (in kWh) does the PICU currently consume and what is the CO2 footprint?
- 2.) How much electricity does standard ICU equipment consume during on, off and standby modes?
- 3.) How long does it take for standard ICU equipment to switch on, and what is the electricity consumption during this period?
- 4.) What are potential behavioural barriers when it comes to switching off equipment?
- 5.) What are potential safety barriers when it comes to switching off equipment?
- 6.) What are the costs and benefits of reducing electricity consumption, based on findings from the prior research questions, for the PICU and for the hospital

Expected type of work
Electricity and CO2 footprint analysis, cost-benefit analysis, multi-criteria analysis, interviews with medical staff (nurses, doctors), technological staff (technicians) and regulatory staff (members taskforce sustainability, members Slim Fit Energy) and possibly design a standard operation procedure/protocol for alternative handling of electrical equipment in the ICU.

Other remarks
All interested students in this subject are encouraged to creatively and proactively make this project their own and come with suggestions for research directions.

References and available resources
- Sustainability mission and vision of Alrijne hospital
- Project with focus on using reusables instead of disposables
- Sustainability policy Alrijne hospital
- Alrijne is cooperating in a project to develop a database with sustainable healthcare alternatives for disposables

Commissioner details
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#07 SH Impact of Pediatric Nutrition

Following the path of medical nutrition in a children's hospital; finding sustainable interventions?

Problem statement:
The Green Deal to improve environmental sustainability in healthcare aims to ultimately improve the impact of healthcare on climate change. As children will undergo the largest impact of climate change pediatric healthcare should take an important responsibility in achieving the Green Deal. Children who are critically ill often depend on enteral nutritional support as most children are not able to eat or drink enough nutrients through the mouth (oral nutrition). This can be regular infant formula, but also specialized medical (probe)feeding or supplements.

Concerns have been raised around the impact of nutrition on the climate emergency. Although this is primarily based on the ratio animal-based versus plant-based nutrition, the impact of suppliers, packaging, preparation protocols, infection-prevention guidelines as well as (plastic) waste procedures is substantial.

Research question(s):
How can we reduce the climate footprint of pediatric nutrition in the PICU?

Sub questions:
- 1.) What are the hot spots in the climate footprint of infant formula in the children's hospital?
- 2.) What are the hot spots in the climate footprint of medical nutrition in the children's hospital?
- 3.) How can we improve the sustainability of infant formula and medical nutrition in the children's hospital?

Expected type of work
Material flow analysis, life-cycle assessment, distributors, and with companies, and possibly design of alternative materials

Other remarks
All interested students in this subject are encouraged to creatively and proactively make this project their own and come with suggestions for research directions.

References and available resources

- 1.) Langyan S et al. (2022) Sustaining Protein Nutrition Through Plant-Based Foods: Front. Nutr. 18
- 2.) Joseph Blessy et al. (2021) Recycling of medical plastics. Advanced Industrial and Engineering Polymer Research.
- 3.) Ellen Cecilie Andresen et al. (2022) Environmental impact of feeding with infant formula in comparison with breastfeeding. Int J Environ Res Public Health

Commissioner details

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#08 SH Perceptions in Plant-based Pediatric Nutrition

Plant-based nutrition for sick hospitalized children; patient and parent perceptions?

Problem statement:
Considering the impact of climate change on children and the need for sustainable healthcare, it is crucial for the healthcare sector to take responsibility and contribute to environmental sustainability. While plant-based nutrition is recognized as beneficial for both human and planetary health, it is important to address the challenges that may arise in implementing these dietary changes, particularly in the context of pediatric healthcare. Sick children may have specific dietary needs or preferences that can make it more difficult to introduce plant-based diets. It is essential to ensure that the nutritional requirements of sick children are met while considering their recovery process.

Involving the perspectives of children, patients, and their parents is indeed critical in successfully transitioning towards plant-based diets. Understanding their needs, preferences, and concerns can help develop strategies that are acceptable and effective in promoting plant-based nutrition. By actively engaging and educating children and their parents about the benefits of plant-based diets for their health and the environment, their acceptance and participation can be enhanced.

By considering the perspectives of children/patients, and their parents, and implementing strategies to address their needs and concerns, the transition towards plant-based diets in pediatric healthcare can be more successful. This approach will not only contribute to sustainable healthcare but also provide a healthier diet for children, promoting their overall well-being.

Research question(s):
How to successfully transition towards Sustainable Plant-based diets for sick children?

Sub questions:
- 1.) What is the perception of healthcare providers, parents and patents of plant-based nutrition?
- 2.) What are the barriers for the implementation of planted-based nutrition?
    - a.) From the perspective of the health care providers
    - b.) From the perspective of the pediatric patient and the parents
- 3.) How can we overcome these barriers?

Expected type of work
Interviews with healthcare workers and parents, distributors, and possibly design of alternative materials, engagement of farmers, Nutritional specialists / nutritionists

Other remarks
All interested students with either technical, clinical or management backgrounds - eg healthcare management, global business and sustainability, industrial ecology, industrial design, biomechanical engineering, medicine, psychology etc- who are passionate about this subject are encouraged to creatively and proactively make this project their own and come with suggestions for research directions.

Commissioner details

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#09 SH Environmental Impact of Healthcare Data use

Increasing use of Artificial Intelligence and Machine Learning in Healthcare: the Sustainability perspective

Problem statement:
Cloud data storage, Artificial intelligence and machine learning (AI/ML) have all found extensive usage in various healthcare domains, including electronic patient files, medical image processing and analysis, as well as continuous health monitoring and management.

Data centres are estimated to be responsible for up to 3% of global electricity consumption today and are projected to touch 4% by 2030. Also, recent data illustrate a noticeable pattern wherein the use of AI/ML are undergoing exponential growth, which presents a significant sustainability challenge. AI/ML systems raise sustainability concerns linked to the natural resources they consume such as electricity and water, and the carbon emissions they produce. At a time where the climate emergency, and in particular the role of climate footprint of healthcare, has become so prominent, these concerns need attention.

However, with its ability to analyse vast amounts of data, learn from patterns, and make decisions in real-time, AI/ML can also be used to improve energy efficiency, reduce waste, and enhance sustainable practices.

In this research project, we would like to tackle this knowledge gap in order to make well-informed decisions about how AI/ML impact Healthcare, and specifically its role in sustainability, and what could be done to mitigate possible negative environmental impacts. We will do this by taking a hospital as a case study for the Healthcare system.

Research question(s):
How can the environmental impact of the increasing use of AI/ML (in healthcare/hospitals) be mitigated?

Possible sub questions include:
- How much data is currently being stored, what is projected in the near future?
- What is the environmental footprint of AI/ML, and what is projected in the near future?
- How can the use AI/ML in Healthcare (hospital) be more sustainable?
- How can AI/Ml be used to improve Sustainable Healthcare?

Expected type of work
This research subject includes: This is a project allowing for much student creativity in how to address the research question. Possible work includes database analysis, surveys, interviews with health practitioners, regulators, data information officers, AI/ML experts, computer scientists and industrial ecologists, as well as data storage, AI/ML companies and other possible third parties. Visual mapping of data flows. Calculations of environmental impacts (including but not limited to CO2 emissions).

Other remarks
We encourage motivated, proactive and independently working students with any study background to apply and co-create the research design as part of the project.

Commissioner details

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“Action must be taken now. From a healthcare perspective, we face a challenge to combat climate change. That change is needed is clear.”

Prof. Dr. Frank Willem Jansen, president of Medical Delta

#10 SH Shit Sensing; Smart and Sustainably

No shit Sherlock - sustainability of utilizing smart incontinence materials (SISs) in aged care

Problem statement:

In the health care sector, aged care is one of the main contributors to the waste pile in the Netherlands (1). Incontinence material accounts for 85.000 tons of waste in the care sector in general, with its main contribution coming from aged care, where about half of all waste relates to incontinence (1; figure 1).

Application of smart incontinence holds benefits for older adults and their caregivers. From a cost/benefit perspective a strong case has already been build for SISs, through a reduction in the amount of times a client (or their bed) needs to be checked on or cleaned (2), although these claims have not yet led to a solid foundation in scientific literature (3). Moreover, the environmental impact (and potential benefit) of using SISs has so far enjoyed little attention. Arguably, considering the reported 26-30% reduction in changes of incontinence material and the 60% reduction in wet bedding (2) and required treatment of less incontinence associated dermatitis, a positive environmental impact seems possible. However, since currently available sensors often only work with single-use in incontinence material, a more thorough analysis is needed.

IJselheem is an aged-care foundation in the region of Zwolle, offering senior living and rehabilitation facilities as well as home care (www.ijsselheem.nl). With this broad scope, IJsselheem is one of the biggest care providers in the region. IJsselheem is currently planning to pilot usage of SISs at one of its living locations to increase quality of care and decrease its environmental footprint. To make the optimal choice in incontinence care for both clients and the environment, more data is needed on the impact of SISs.

Research question(s):

■ **1.) What is the impact of using SISs on...**
a.) Quality of care
b.) The client
c.) The caregiver and healthcare professional
d.) The organization

■ **2.) What is the environmental impact of using SISs in comparison to conventional continence material (lifecycle analysis)?**

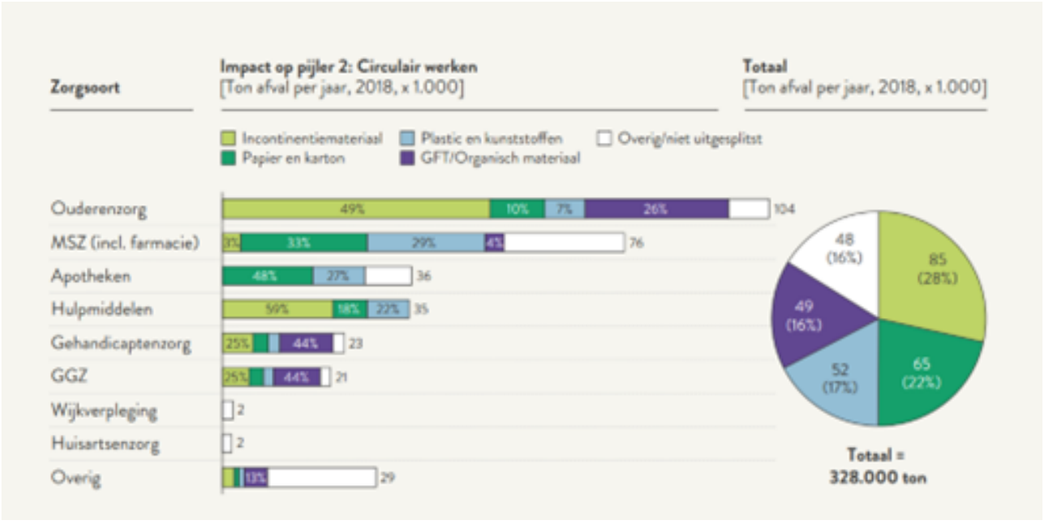

Figure 1. Impact of care type on circularity, with aged care ('ouderenzorg'; top row) as the sector causing most waste, with incontinence material (light green) as the main contributor. Figure adopted from (1).

Expected type of work

Scientific research; qualitative and quantitative (for example interviews, focus-groups), LCA smart incontinence materials.

Other remarks

We encourage motivated, proactive and independently working students with any study background to apply and co-create the research design as part of the project.

References and available resources

■ 1.) https://www.vilans.nl/kennisbank-digitale-zorg/slim-incontinentiemateriaal
■ 2.) https://open.rws.nl/publish/pages/183723/ce_delft_220218_milieu-impact_van_wasbare_en_eenmalige_luiers_def-toegankelijk.pdf
■ 3.) De inhaalrace naar duurzame zorg, Gupta Strategists, juni 2022, https://gupta-strategists.nl/storage/files/De-inhaalrace-naar-duurzame-zorg.pdf (pag. 16)
■ 4.) Anders Werken Slimme Inco factsheet, Vilans, november 2021, https://www.vilans.nl/kennisbank-digitale-zorg/slim-incontinentiemateriaal
■ 5.) Omotunde, M., & Wagg, A. (2023). Technological solutions for urinary continence care delivery for older adults: A scoping review. Journal of Wound, Ostomy and Continence Nursing, 50(3), 227-234.

Commissioner details

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#11 SH Decrease Driving with Disposables

Decrease driving with disposables: the impact of disposables on board of ambulances

Problem statement:
Ambulances deliver ambulant acute care; on any given incoming call, ambulance personal performs basic medical assessment. From diagnostic assessment to acute therapy. Following such initial diagnostics and therapy, patients are either transported to a hospital or can be trusted to the care of their GP at home depending on the severity of their condition. These medical procedures entail the use of equipment which have environmental impact. These impacts are due to procedures similar to a hospital emergency room or a GP's assessment: disposable equipment is used to assess the vital signs such as blood pressure, temperature but also first diagnostics such as drawing blood and performing an EKG. Giving initial therapy mainly consists of giving oxygen, injecting medication or inhalation medication also results in waste and pollution.

The ambulance service in region Hollands-Midden (RAVHM) aims to align with the Climate accord and Green Deal sustainable healthcare (1) and reduce their environmental footprint. The RAVHM is an independently organized service with 40 ambulances, 300 personnel doing 60.000 calls annually. Their region spans from Hillegom to Schoonhoven 810 km2 surface and houses 800.000 inhabitants and attracts a vast number of tourists in the summer period, increasing the number of inhabitants even more.

The RAVHM is collaborating with 3 hospitals in their region, also serving other hospitals in the Netherlands. Reducing their footprint is a challenge in logistics, material use and economics.

In this assignment, the focus is on material use on board of the ambulance. For example, use of bloodpressure bands, blood drawing equipment and EKG-disposable equipment. Impact analysis of the ICU has demonstrated the importance of a thorough knowledge base of the hotspots. In a study by Hunfeld et al, items such as gloves were demonstrated to have a disproportional large environmental impact (2). To our knowledge, no such analysis exists for ambulances. Healthcare specific databases do incorporate frequently used items, such as syringes (3) and we suspect that research done by the green ER is most affiliated to materials used in ambulances, as they both deal with acute care settings (4). However, this is currently a clear knowledge gap.

Research question(s):
What is the most impactful disposable material that should be eliminated on board of the ambulance?
Sub questions:
- 1.) Which disposable material is used most?
- 2.) Which disposables have a technically feasible and available reusable alternative?
- 3.) If not: can these disposables be safely reused more than once?

NB: constraining factors include:
- Alternatives must comply with the applied rules and regulations, for example the hygiene regulations ambulancezorg and patient safety (ISO/NEN/HKZ) (5) and the national used ambulance protocol (LPA9) (6).
- Health insurance companies demand that operating cost are kept as low as possible within the range of the pending rules and regulations.

Commissioner details

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#12 SH Environmental Impact in Acute Ambulance Care

Get a grip on chest pain: assessment of environmental impact of acute ambulance care

Problem statement:

Ambulances deliver ambulant acute care; on any given incoming call, ambulance personal performs basic medical assessment. From diagnostic assessment to acute therapy. Following such initial diagnostics and therapy, patients are either transported to a hospital or can be trusted to the care of their GP at home depending on the severity of their condition. These medical procedures entail the use of equipment which have environmental impact. These impacts are due to procedures similar to a hospital emergency room or a GP's assessment: disposable equipment is used to assess the vital signs such as blood pressure, temperature but also first diagnostics such as drawing blood and performing an EKG. Giving initial therapy mainly consists of giving oxygen, injecting medication or inhalation medication also results in waste and pollution.

The ambulance service in region Hollands-Midden (RAVHM) aims to align with the Climate accord and Green Deal sustainable healthcare (1) and reduce their environmental footprint. The RAVHM is an independently organized service with 40 ambulances, 300 personnel doing 60.000 calls annually. Their region spans from Hillegom to Schoonhoven 810 km2 surface and houses 800.000 inhabitants and attracts a vast number of tourists in the summer period, increasing the number of inhabitants even more. The RAVHM is collaborating with 3 hospitals in their region, also serving other hospitals in the Netherlands. Reducing their footprint is a challenge in logistics, material use and economics.

In this assignment, we will focus on analysing the impact of the most frequent diagnostic procedure.

'Pain on the chest' is the most frequently responded to call, which entails a standard procedure of diagnostics and therapeutics. To be able to reduce the environmental footprint of ambulances, it is important to determine which aspects of these procedures are most polluting and why.

Impact analysis of the ICU has demonstrated the importance of a thorough knowledge base of the hotspots. In a study by Hunfeld et al, items such as gloves were demonstrated to have a disproportional large environmental impact (2). To our knowledge, no such analysis exists for ambulances. Healthcare specific databases do incorporate frequently used items, such as syringes (3) and we suspect that research done by the green ER is most affiliated to materials used in ambulances, as they both deal with acute care settings (4). Previously, assessments of healthcare processes ('zorgpaden') have been performed by other students of this lab, such as for greening delivery (5). However, this is currently a clear knowledge gap.

Research question(s):

- **What is the life cycle of the procedures on board of an ambulance in response to a 'pain on the chest' call?**
- **Where are the environmental hotspots?**
- **What are possibilities to reduce the footprint effectively and efficiently within this procedure?**

Sub questions:

- Which materials are used and what are the impacts?
- Which drugs are administered and what are the impacts?
- Comparison of procedure to other ambulance services and standard of care in NL or abroad

NB: constraining factors include:

- Alternatives must comply with the applied rules and regulations, for example the hygiene regulations ambulance care and patient safety (ISO/NEN/HKZ) (5) and the national used ambulance protocol (LPA9) (6).
- Health insurance companies demand that operating cost are kept as low as possible within the range of the pending rules and regulations.

Expected type of work

Literature review, assessment of material flow on ambulance (field work), hotspot analysis, review of standards of care

Other remarks

The assignment is open to any student that is enthusiastic for this topic and a willingness to learn. Feel free to add or elaborate this assignment fitting to your own expertise. A proactive attitude is encouraged!

References and available resources

- 1.) Green Deal Duurzame Zorg
- 2.) Hunfeld, N., Diehl, J.C., Timmermann, M. et al. Circular material flow in the intensive care unit—environmental effects and identification of hotspots. Intensive Care Med 49, 65–74 (2023). https://doi.org/10.1007/s00134-022-06940-6
- 3.) HealthcareLCA | Data driven sustainable health care
- 4.) De Groene SEH
- 5.) https://www.rivm.nl/hygienerichtlijnen/ambulancezorg
- 6.) https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg

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#13 SH Pharmaceutical Waste in Ambulance Care

Reducing pharmaceutical waste in ambulance care

Problem statement:

Ambulances deliver ambulant acute care; on any given incoming call, ambulance personal performs basic medical assessment. From diagnostic assessment to acute therapy. Following such initial diagnostics and therapy, patients are either transported to a hospital or can be trusted to the care of their GP at home depending on the severity of their condition. These medical procedures entail the use of equipment which have environmental impact. These impacts are due to procedures similar to a hospital emergency room or a GP's assessment: disposable equipment is used to assess the vital signs such as blood pressure, temperature but also first diagnostics such as drawing blood and performing an EKG. Giving initial therapy mainly consists of giving oxygen, injecting medication or inhalation medication also results in waste and pollution.

The ambulance service in region Hollands-Midden (RAVHM) aims to align with the Climate accord and Green Deal sustainable healthcare (1) and reduce their environmental footprint. The RAVHM is an independently organized service with 40 ambulances, 300 personnel doing 60.000 calls annually. Their region spans from Hillegom to Schoonhoven 810 km2 surface and houses 800.000 inhabitants and attracts a vast number of tourists in the summer period, increasing the number of inhabitants even more. The RAVHM is collaborating with 3 hospitals in their region, also serving other hospitals in the Netherlands. Reducing their footprint is a challenge in logistics, material use and economics.

In this assignment, we aim to reduce to footprint of pharmaceuticals. Research around pharmaceutical waste knows different aspects, e.g. impact in production, in logistics, unused pharmaceuticals and adverse effects of pharmaceuticals in the environment namely water pollution (2). From practical experience, ambulance personnel has noticed that there are frequently prescribed medications that of which the administration dose does not match the packaging. For example, the drug adenosine is available only in 6 mg bottles, while its use is up to 36mg, thereby producing 6 empty bottles. Similarly, the drug ascal is always used in a dosage of 300mg, but the units are in 100mg packaging. In winter, one of the most used acute therapy is inhalation medication. The impact of inhalation medication has been demonstrated to be very dependent on which type. Similarly, a recent campaign has been started in the Erasmus MC hospital to advocate for less intravenous paracetamol use, as its impact is much higher while medically, it is often unnecessary (3,4).

Therefore, measuring the impact of these drugs and the possibilities of alternative packaging, alternative drugs or administration routes could reduce the footprint of ambulances.

Research question(s):

What is the most impactful disposable material that should be eliminated on board of the ambulance?

Sub questions:

- 1.) What are the hotspots in drug use in ambulances?
- 2.) What are the most effective and efficient ways to reduce environmental impact while maintaining or improving quality of care?

NB: constraining factors include:

- Alternatives must comply with the applied rules and regulations, for example the hygiene regulations ambulance care and patient safety (ISO/NEN/HKZ) (5) and the national used ambulance protocol (LPA9) (6).
- Health insurance companies demand that operating cost are kept as low as possible within the range of the pending rules and regulations.

Expected type of work

Literature review, assessment of material flow (drug use) on ambulance (field work), hotspot analysis.

Other remarks

The assignment is open to any student that is enthusiastic for this topic and a willingness to learn. Feel free to add or elaborate this assignment fitting to your own expertise. A proactive attitude is encouraged!

References and available resources

- 1.) Green Deal Duurzame Zorg
- 2.) Hunfeld, N., Diehl, J.C., Timmermann, M. et al. Circular material flow in the intensive care unit—environmental effects and identification of hotspots. Intensive Care Med 49, 65–74 (2023). https://doi.org/10.1007/s00134-022-06940-6
- 3.) HealthcareLCA | Data driven sustainable health care
- 4.) De Groene SEH
- 5.) https://www.rivm.nl/hygienerichtlijnen/ambulancezorg
- 6.) https://www.ambulancezorg.nl/themas/kwaliteit-van-zorg/protocollen-en-richtlijnen/landelijk-protocol-ambulancezorg

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#14 SH Circular Syringes

Bulk or batch: how to make syringes circular?

Problem statement:

Healthcare contributes to environmental damage through its high greenhouse gas emissions and use of materials – and production of waste. As Haga Hospital, we want to reduce our environmental footprint. Besides energy use reduction we are investigating how to reduce material use and waste production. Previously, Hunfeld et al showed that syringes were the second largest contributor of CO2 emissions and among the top 5 waste causes in the ICU (2). However, there are no additional data for other hospitals and hospital departments. On the other hand, the use of pre-filled syringes has been argued to contribute to reduction of pharmaceutical waste and improved patient safety (3).

This initiative concerns the central production of custom-made mediation syringes. Based on visual observations, this central production is assumed to reduce the use of (single-use) plastics. In the current working method this often concerns syringes for single use. Besides the fact that we would like to map out the costs for waste and working methods, we also want to determine, in fact, whether and, if so, what reduction this would mean in terms of the environmental footprint.

In concrete terms, this means that we include the changes to the impact on the environment, the associated actions (purchasing, waste, product processing, sterilization costs and microbiological monitoring) as well as the costs of the intended change compared to the current working method for at least 3 products, including NaCl 0.9% 50 ml syringes, cefazolin (2g) syringes and possibly ephedrine 5 mg-ml 5 ml syringes with two new variants:

- Variant 1: bulk made by hospital pharmacy
- Variant 2: batch delivered from AHZ

The general idea is that the alternatives are advantageous in terms of actions, work, costs and environmental impact for both the Haga Hospital and any external customers compared to the current working method.

Research question(s):

What is the optimal use of preparation of syringes with respect to lowering environment impact and optimizing for cost-effectiveness?

Sub questions:

- How many bulk and batch syringes are used? What are the applications and are these appropriate? By which departments?
- What is the environmental footprint of bulk and batch syringes?
- What are the costs-benefits of bulk and batch syringes?
- Are there other alternatives to use of syringes? Are there best-practices from other healthcare organisations?

Expected type of work

This research subject includes:

- LCA like approach to determine environmental impact and
- Financial impact comparison
- Inventory of changes in work-flow
- Interviews with involved employees
- Gather information on legal and hygienic requirements

Other remarks

About the organization: Haga Hospital is made up of 7 Result Responsible Units (RVEs) with support from staff services. Staff boards and advisory councils are closely involved in the development of hospital policy. Juliana Childrens Hospital is also part of the Haga Hospital. Since 1 March 2023 the Haga Hospital and the LangeLand Hospital in Zoetermeer have merged. On June 1st the name changes into Haga hospital Zoetermeer.

Commissioner details

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#15 SH Critical Materials

Get a grip on critical materials

Problem statement:

■ **Inventory, impact and management of Critical raw materials in hospitals**

Raw materials are crucial to Europe's economy. They form a strong industrial base, producing a broad range of goods and applications used in everyday life and modern technologies. Reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. To address this challenge, the European Commission has created a list of critical raw materials (CRMs) for the EU. CRMs combine raw materials of high importance to the EU economy and of high risk associated with their supply (1).

Although the domestic production of certain critical raw materials exists in the EU, in most cases the EU is dependent on imports from non-EU countries. For example, China provides 100 % of the EU's supply of heavy rare earth elements (REE), Turkey provides 99% of the EU's supply of boron, and South Africa provides 71% of the EU's needs for platinum and an even higher share of the platinum group metals iridium, rhodium, and ruthenium. The risks associated with the concentration of production are in many cases compounded by low substitution and low recycling rates.

In 2023, a second foresight study (2) assesses 15 technologies mapped to 5 strategic sectors. The update of the study gives a current picture of the technologies' materials demand in 2030 and 2050, and provides a more complete picture of the technologies needed to reach the EU's strategic goals. The study also served as supporting evidence in the development of the Critical Raw Materials Act and the list of strategic raw materials. Although health care uses a lot of CRMs in their equipment, appliances and pharmaceuticals (?), health care was not part of the investigated strategic sectors. Haga investigated its own materials in a student project (3,4).

That is why Haga wants to know in more detail how vulnerable the hospital is with regards to the use of CRMs. A first inventory shows that health care could be impacted greatly.

Haga hospital and hospitals in general have little insight into the types and quantities of CRMs they use and what impact market, geopolitical or availability aspects can have on the performance and sustainability of their care tasks. In order to increase their environmental sustainability as well as their procurement sustainability, hospitals need to incorporate insight in CRMs in their management decisions. Therefore, hospitals are in need of a "tool" that could help them to A) determine the different aspect of vulnerability, B) the different implications and C)) the severity of the implications. At the same time hospitals are in need of measures to reduce the vulnerabilities because of the use of CMRs.

With this tool, hospitals next need to work on solutions. Either by decreasing CRMs in the products they purchase, working together with manufacturers, or by increasing the 'waste' of CRMs.

Research question(s):

The research contains 3 elements: continuous CRM assessment, decreasing CRMs inflow and decreasing CRMs outflow of the hospital.

■ **ASSESSMENT TOOL.** Which assessment framework (tool) will help hospitals to assess their vulnerability (consequences and impacts) of using CRM, including an overview of detailed mitigation measures.

a. Which existing frameworks already exist?
b. What is their compatibility with hospital systems?
c. If no frameworks exist, define what a new framework needs to incorporate and if possible, design the framework

■ **CASE STUDY.** The information position of the hospital must be improved in order to be able to make well-founded decisions with regard to reducing dependence on the CRMs. This means that hospitals need to gather information about the equipment, appliances and medicine they use that contain CRMs. They need to be aware of the kind and amount of CRMs that suppliers use. Therefore, hospitals need to know which steps they can take to improve the available information about the usage of CRMs before they are able to develop measures to reduce their dependency on CRMs.

■ **KEEP MATERIALS IN THE CHAIN.** Investigate the possibilities of keeping CRMs used in hospital equipment (in the hardware). What can hospitals do together with developers and suppliers to make sure that CMRs that are used in equipement and appliances (like serinces) stay available for hospitals (create a dedicated loop of these CRMs and medicines available after use and can be reused by the supplier for the same or another healthcare application or via the supplier for another application. This in a more general sense, perhaps based on a best case that we can find out in the hospital or in other hospitals. This could include technical possibilities, but also specific circular business model possibilities such as product-as-a-service solutions.

■ **IMPROVED EFFICIENT USAGE:** Analysis of possibilities to implement efficiency improvements in the use and consumption of CRM's of health care consumables, like medicine, contractfliuds, coolant (like helium in MRI's etc). Increasing efficiency in usage also reduces dependency. Improving efficiency can have an impact on the way of working, may also conflict with supplier provisions and/or purchasing aspects and perhaps on peripheral equipment.

Expected type of work

This research subject includes:

■ Research assessment CRMs tools
■ Designing assessment tool
■ Interviews with stakeholders such as purchasing department, management, finance
■ Interviews with manufacturers

Remarks

The 4 research questions may be addressed separately by different students depending on their background and time availability. Students with all backgrounds interested in this topic are encouraged to apply and adapt the research proposal to fit their expertise and interest in collaboration with the supervisor.

About the organization: Haga Hospital is made up of 7 Result Responsible Units (RVEs) with support from staff services. Staff boards and advisory councils are closely involved in the development of hospital policy. Juliana Childrens Hospital is also part of the Haga Hospital. Since 1 March 2023 the Haga Hospital and the LangeLand Hospital in Zoetermeer have merged. On June 1st the name changes into Haga hospital Zoetermeer.

Commissioner details

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#16 SH Cellulose Pads

Implementation of reusable fluid mats in the obstetric ward

Problem statement:
Healthcare contributes for 7% to the national CO2 footprint. Part of this is due to a large amount of disposable materials in the hospital. Multiple studies have shown that most disposable products have a greater environmental impact compared to reusables. To reduce this environmental impact, it is necessary to gain knowledge about the environmental impact of products and services, to be able to make an environmentally sound choice. The next step is to implement the use of a sustainable alternative and investigate the use preferences and acceptability of this particular product.

Cellulose pads are utilized across multiple hospital departments to effectively absorb moisture, blood, and fluids. Notably, extensive research has revealed that the Obstetrics Department at Leiden University Medical Centre (LUMC) stands out as the primary consumer of cellulose pads, with an annual usage exceeding 50,000 pads. It has also become evident that there is potential to reduce their consumption in various areas. Subsequent research have highlighted the substantial environmental impact associated with disposable cellulose pads, which is more than three times greater than that of reusable alternatives. Given the environmental concerns, transitioning to reusable absorbent mats is a favourable option. However, the Obstetrics Department lacks experience in working with reusable mats, and it is essential to ascertain whether healthcare professionals and patients find them an promising substitute.

To address this, we are conducting a pilot study to assess the acceptability of using reusable absorbent mats. We would like to combine this with research that aims to gather insights into user preferences, functionality and comfort. Moreover, it provides an opportunity to explore the feasibility of implementing reusable mats throughout the entire hospital.

Research question(s):
How is the user acceptability of reusable mats compared to disposable cellulose pads for usage in the obstetric ward?
- **How is the practicality of the reusable absorbent mat compared to the cellulose pad for nurses, midwives and doctors? How is the functionality of the reusable absorbent mat?**
- **Is there a reduction of use compared to the disposable cellulose pad?**
- **How is the comfort of the reusable alternative for the patient?**
- **How can the reusable absorbent mat be implemented? How is the feasibility for other departments?**
- **Is redesign needed? What is exactly needed?**

Suggested academic background
This research assignment is open to any graduating Master students from Leiden University, TU Delft and Erasmus Rotterdam
The assignment can be tailored to align with the requested study.
- Health Sciences
- Technical Medicine (Clinical Technology)
- BioMedical Engineering
- Industrial Design Engineering
- Medicine

Expected type of work
- Qualitative research and business case during pilot study
- Redesign of reusable absorbent mat

Commissioner details
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#17 SH Barometer

Barometer Green OR: Recommendations to reduce the Dutch operating room's CO2 footprint

Problem statement:
The healthcare sector contributes to 7% of the national CO2 emissions. Although operating rooms (ORs) occupy only 6% of the total floor space in hospitals, they are responsible for a staggering 30% of the generated waste. With the goal of making ORs more sustainable, the Leiden University Medical Center (LUMC), Radboud University Medical Center (Radboud UMC), and Radboud University, in collaboration with Gupta Strategists, have initiated the 'Barometer Green OR' project. The Barometer is part of the National Green OR Network and is subsidized by the Ministry of Health, Welfare, and Sport (VWS). This Barometer provides insight into the CO2-footprint of Dutch ORs and offers participating hospitals practical tools to make their ORs more sustainable.

In 2023, this Barometer was employed to furnish participating hospitals with an advisory report containing essential recommendations for reducing their OR's CO2 footprint. We aim to assess the execution of these recommendations and ascertain whether hospitals are effectively utilizing both the report and the suggested measures.

Research question(s):
- **To what extent are hospitals making effective use of the report?**
- **Did the report impart new information to the hospitals?**
- **Have hospitals adopted the report for implementing new measures, and is this implementation feasible?**
- **What should be included in an upcoming new Barometer?**

Suggested academic background
This research assignment is open to any graduating Master students from Leiden University, TU Delft and Erasmus Rotterdam
The assignment can be tailored to align with the requested study.
- Health Sciences
- Technical Medicine (Clinical Technology)
- BioMedical Engineering

Expected type of work
Qualitative research (interviews/survey), redesign of barometer questionnaire based on literature and possibility to do it from own research

Available data/reports or other relevant information sources for the assignment
https://degroeneok.nl/themas/barometer-groene-ok/

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Excited?
Please contact us or register online