Mitigating the Environmental Impacts of Equipment Used in Healthcare through Lifecycle Evaluation

Prepared by:
Pooya Pourreza, UBC Sustainability Scholar, 2022

Prepared for:
Kelsey McGivern and Marianne Dawson, Vancouver Coastal Health

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Declaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Vancouver Coastal Health staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Vancouver Coastal Health or the University of British Columbia.

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1 Introduction

1.1 Vancouver Coastal Health

Vancouver Coastal Health (VCH) is one of the largest healthcare organizations in British Columbia, Canada, and is dedicated to providing quality healthcare services to the communities it serves. The organization operates a diverse range of healthcare facilities, including:

- Hospitals: VCH operates several acute care hospitals, including Vancouver General Hospital and St. Paul's Hospital, which provide a full range of medical services, including emergency care, diagnostic imaging, and specialized services such as oncology, cardiology, and neuroscience.
- Long-term care facilities: VCH operates several long-term care facilities, providing elderly and disabled individuals with ongoing care and support.
- Community clinics: VCH operates community clinics, offering a range of primary care services such as family medicine, pediatrics, and women's health.
- Mental health and addiction services: VCH provides mental health and addiction services, including crisis support, counselling, and support groups, to individuals struggling with mental health and substance abuse issues.

VCH is committed to providing high-quality healthcare services in a sustainable and environmentally friendly manner. This project is defined as the collaboration between its Equipment Planning and Energy & Environmental Sustainability teams, which aims to incorporate energy-efficient and sustainable technologies into its healthcare facilities.

All in all, VCH is a vital component of the healthcare system in British Columbia. It is dedicated to improving the health and well-being of the communities it serves. With a focus on sustainability and high-quality care, VCH is well-positioned to meet the evolving healthcare needs of the people of the Vancouver Coastal region.

1.1.1 Equipment Planning Team

The Equipment Planning (EP) team of VCH is responsible for the planning, procurement, and managing medical equipment and technology within the organization. Their primary function is to ensure that the right equipment is in the right place at the right time for patient care. This includes identifying equipment needs, researching and evaluating new equipment, and making recommendations for purchase. The team also manages the budget for equipment purchases and works closely with other departments within VCH to ensure that equipment is used effectively and efficiently. The EP team is also responsible for equipment maintenance, repair and replacement. They are essential in ensuring that VCH has the necessary equipment to provide high-quality care to patients. Finally, the EP team works with clinical stakeholders, architects, contractors, and facilities teams to develop a set of equipment specifications that ultimately inform what equipment is purchased for a renovation or redevelopment project. This ranges from fixed medical equipment (e.g., MRI, CT

Scanners, surgical equipment) to mobile medical equipment (e.g., vital sign monitors, ventilators, hospital beds and stretchers) to non-medical equipment (e.g., fume hoods, sterilizers and disinfectors, storage solutions).

1.1.2 Energy & Environmental Sustainability Team

The Energy & Environmental Sustainability (EES) team of VCH is responsible for developing and implementing policies and programs to promote energy efficiency and reduce the environmental impact of VCH operations. The team's main objective is to minimize the environmental footprint of VCH and to promote sustainable practices within the organization. The EES team works closely with other departments within VCH to identify opportunities to improve energy efficiency, reduce greenhouse gas emissions, and promote sustainable practices such as recycling, composting and reducing waste. The team also monitors and reports on VCH's energy usage, emissions and waste streams and sets targets for improvement. The team may also be responsible for implementing green building and infrastructure design, renewable energy projects, and promoting sustainable transportation options. They play a vital role in ensuring VCH's operations are environmentally responsible and sustainable.

1.2 Sustainable Procurement

Sustainable procurement is an important aspect of corporate social responsibility and is becoming increasingly popular as companies seek to reduce their environmental footprint and demonstrate their commitment to sustainability. The process of green procurement involves evaluating the environmental impact of different products and services, from sourcing raw materials to the disposal of the final product. This includes considering factors such as the carbon footprint, waste generation, and resource usage of the products and services being procured.

Sustainable procurement helps organizations adopt environmentally friendly practices and reduce their carbon footprint. It also encourages suppliers to adopt sustainable practices and supports the development of more environmentally friendly products and services. This can have positive impacts on both the environment and the bottom line, as companies that adopt green procurement practices can reduce costs through more efficient resource use, lower energy consumption, and reduced waste. Moreover, it helps organizations build and maintain a positive reputation as consumers become increasingly conscious of the environmental impact of the products they buy.

By demonstrating a commitment to sustainability, companies can differentiate themselves from their competitors and attract customers who value environmentally responsible products and services. Lastly, sustainable procurement is a valuable tool for organizations seeking to reduce their environmental impact, promote sustainability, and improve their reputation. By carefully selecting products and services that have a minimal impact on the environment, companies can play an important role in addressing some of the world's most pressing environmental challenges.

1.3 Life Cycle Assessment

Life Cycle Assessment (LCA) is a tool used to assess the environmental impact of a product or service throughout its entire life cycle. LCA is an in-depth analysis that considers all the stages of a product or service's life, from raw material extraction to disposal. It includes the impacts of production, use, and end-of-life disposal (Tukker 2000). It typically includes the following steps:

- Definition of the scope and boundaries of the study: The scope of the study is defined, including the products or services being evaluated, the functional unit, and the system boundaries.
- Inventory analysis: The data collection stage, where data is gathered on the inputs and outputs of the product or service, including raw materials, energy, water, emissions, and waste.
- Impact assessment: The quantitative evaluation of the environmental impacts, such as greenhouse gas emissions, energy use, land use, water use, and waste generation.
- Interpretation: The final step, where the results of the analysis are interpreted and recommendations are made for reducing the environmental impact of the product or service.

It is a valuable tool for organizations seeking to reduce their environmental impact, as it provides a comprehensive understanding of the life cycle environmental impacts of a product or service. This information can identify improvement areas, make informed decisions about product and service selection, and support the development of more sustainable products and services. In addition, it can also be used to support the development of sustainability standards and certification programs, such as the Cradle to Cradle certification and the EU Ecolabel. By providing a comprehensive understanding of the environmental impact of a product or service, LCA can support organizations in achieving their sustainability goals and advancing environmental sustainability.

This method aims to identify the environmental impacts associated with a product or service, including the use of energy, water, and other resources, as well as the generation of waste and emissions. This information can be used to make informed decisions about product and service selection, identify improvement opportunities, and evaluate the overall sustainability of an organization's operations (Curran 2013).

LCA considers three main areas of impact:

- Resource depletion: The impact of extracting and processing raw materials, including the use of energy, water, and other resources.
- Environmental pollution: The impact of emissions and waste generated during the production, use, and disposal of a product or service.
- Human health: The impact on human health of exposure to pollutants and hazardous materials associated with a product or service.

It can be used to compare different products or services, to identify the environmental impacts of a specific product or service, and to support decision-making about product and service selection. By providing a comprehensive understanding of the environmental impact of a product or service, LCA can support organizations in reducing their environmental footprint and advancing sustainability.

In summary, LCA is a powerful tool for organizations seeking to understand the environmental impact of their products and services and to advance sustainability. By providing a comprehensive analysis of the life cycle environmental impacts, LCA can support organizations in reducing their environmental footprint and making informed decisions about product and service selection.

1.4 Motivations and Objectives

One of the leading greenhouse gases contributing to climate change is carbon dioxide (CO_2), and the healthcare industry is a significant source of CO_2 emissions. The energy consumption of healthcare facilities, staff and patient transportation, and medical waste disposal are the main sources of CO_2 emissions in the healthcare sector.

- Energy consumption: Hospitals and other healthcare facilities use a lot of energy to run lighting, heating, cooling, and medical equipment. This energy is typically generated by burning fossil fuels such as coal, natural gas, and oil, which release CO2 into the atmosphere. According to Bawaneh et al. 2019, the healthcare industry uses about 10 percent of the total energy consumed in the US.
- Transportation: The transportation of patients and staff to and from healthcare facilities also produces emissions for the healthcare sector. This can involve driving a personal car, an ambulance, or a helicopter. These modes of transportation emit CO_2 into the atmosphere by burning fossil fuels.
- Medical waste: Medical waste produced by the healthcare industry includes sharps (needles and other sharp objects), pharmaceuticals, and hazardous materials. The improper disposal of this waste poses a risk to human health and can pollute the air, water, and soil.

In general, the healthcare sector contributes significantly to CO_2 emissions. Therefore, it is necessary to take action to lessen this impact through sustainable practices, such as investing in renewable energy projects to offset emissions, recycling, waste reduction, and green procurement. According to some estimates, the healthcare industry could adopt sustainable practices and renewable energy sources to reduce its carbon footprint significantly. For example, Emissions from health services were 25 megatonnes of carbon dioxide equivalent in 2019, which is a 26% decrease since 1990 in England (Tennison et al. 2021).

This research project aims to develop a set of criteria to evaluate the environmental impact of the lifecycle of equipment commonly purchased for healthcare facilities. The evaluation criteria developed through this project will act as the foundation for integrating environmental considerations into the equipment planning process and embed environmental considerations and Planetary Healthcare principles into the assessed value of equipment purchased for any new facility.

2 Background

This section provides the background on Sustainable Procurement and Life Cycle Assessment for a comprehensive coverage of the topic.

2.1 Sustainable Procurement

The healthcare industry is one of the largest and fastest growing sectors in the world, with approximately 2.8 million hospital beds in Europe alone and a significant proportion of national budgets in developing countries being spent on healthcare (Duane et al. 2019). In the United States, the healthcare sector accounts for nearly 18% of the GDP and spends around $320 billion annually on goods and services (Campion et al. 2015). The sector's importance in promoting sustainability is significant due to its critical role in society and its immense purchasing power. The healthcare industry has the potential to make a considerable impact on sustainability in three primary ways:

The first major way in which the health sector can contribute to sustainability is by recognizing its inherent link to sustainability, and the impact that sustainability conditions can have on public health (Borgonovi and Compagni 2013). Environmental safety and socioeconomic well-being, for instance, are closely tied to societal health and can play a significant role in disease prevention (Duane et al. 2019). Therefore, sustainability strategies such as sustainable public procurement can help the health sector fulfill its mandate of promoting a healthy society by proactively preventing diseases through improved social, economic, and environmental sustainability practices.

Secondly, the procurement of healthcare-related goods, equipment, infrastructure, energy, and services requires a substantial amount of financial resources. In the United States alone, the annual expenditure on these items amounts to around $320 billion (Campion et al. 2015). Given the large purchasing power of the health sector, it has the ability to directly impact sustainability outcomes through the procurement of environmentally friendly and sustainable goods and services. Additionally, the substantial financial resources involved in healthcare procurement can be harnessed to encourage the production, supply, and consumption of sustainable products and services.

Thirdly, the healthcare industry is a major contributor to environmental pollution and generates a significant amount of waste, including pathological, pharmaceutical, and chemical waste (Ryan-Fogarty et al. 2016). In the United States alone, hospitals produce over 5.9 million tonnes of waste annually, accounting for 8% of the country's carbon dioxide emissions and consuming about 10% of the nation's overall energy consumption (Zhu et al. 2018). Despite the adoption of single-use medical devices to reduce the risk of infection, many of these devices are unnecessary and lead to environmental hazards (Unger and Landis 2016). However, the health sector can reduce its carbon footprint and promote environmental sustainability through practices such as reprocessing medical devices, minimizing resource consumption and waste generation, and adopting energy and water-efficient practices, green building, and eco-friendly product design (Ryan-Fogarty et al. 2016).

To develop sustainable solutions for the health sector, it is essential to conduct more research on sustainable procurement practices in this field (Campion et al. 2015). However, there is currently a scarcity of research in this area, as highlighted by several studies (Chiarini et al. 2017; Zhu et al. 2018). To address this problem, it is necessary to focus on increasing research on sustainable procurement practices problems in the health sector, particularly in developing countries, where research in this area is limited (Leal Filho et al. 2019). This will help to develop sustainable solutions that can promote social, economic, and environmental sustainability in the health sector.

2.2 Life Cycle Assessment

To establish sustainable health systems, evaluating the environmental impacts of healthcare is a necessary first step. By identifying the activities that have the greatest impact and offering alternatives that are more environmentally friendly, such evaluations generate momentum for policy change based on empirical evidence. Two primary methods are used to measure the environmental impacts of healthcare activities: process-based life cycle assessment (LCA) and economic input-output analysis.

LCA is an internationally standardized methodology that quantifies the environmental impacts associated with the entire lifecycle of a given product, process, or service, from production through disposal. This method uses a "bottom-up" approach to measure the energy and materials entering and leaving a defined system, along with their environmental impacts. This approach is particularly precise and appropriate for assessing the environmental impacts of products, such as medical equipment and pharmaceuticals.

Economic input-output analysis, also known as environmental input-output analysis or economic input-output life cycle assessment (EIO-LCA), examines the relationships between various sectors of the economy by assigning environmental impacts to the system of interest using aggregate expenditure data. This "top-down" approach is well-suited for estimating the impacts of complex systems, such as hospitals or entire health systems, where a process-based LCA approach is not feasible or practical.

In recent years, there has been a proliferation of systematic reviews examining the environmental effects of various aspects of healthcare, including surgical procedures, patient care options, and medical instruments such as laparoscopic equipment. For example, Rizan et al. 2020 examined the carbon footprint of surgical operations, which are typically the most resource-intensive area of a hospital and contribute significantly to waste. The study aimed at identifying opportunities to improve the environmental impact of surgery by evaluating existing literature. Alshqaqeeq et al. 2020 conducted a systematic literature review to analyze peer-reviewed articles that provide quantitative information related to medical-based decisions in any of the 12 subdivisions of a representative hospital. These subdivisions were developed from U.S EPA studies on hospitals as a comprehensive set of emissions. The study followed the guidelines for reporting LCA data in healthcare by Zumsteg et al. 2012.

More recently, Sousa et al. 2021 reviewed studies that use the LCA or eco-design methodology to assess the environmental impacts of medical devices, either through singular application or simulation. To provide a comparative analysis, the review includes LCA studies on the most commonly used material in the medical device industry: polymers. Keil et al. 2022 aimed to evaluate the environmental impact of substituting single-use healthcare products with reusable ones through a systematic review of comparative cradle-to-grave LCAs. The main focus was to identify changes in the environmental impact resulting from this substitution. As no standardized transparency checklist was available, the authors developed a transparency checklist using DIN ISO 14040/14044. The final checklist included 22 criteria used to appraise the included studies.

3 Methodology

In this section, the evaluation framework developed for greening the procurement process of VCH is defined. Several steps need to be taken to evaluate the environmental impacts of each piece of equipment. Figure 1 shows the flowchart of this framework.

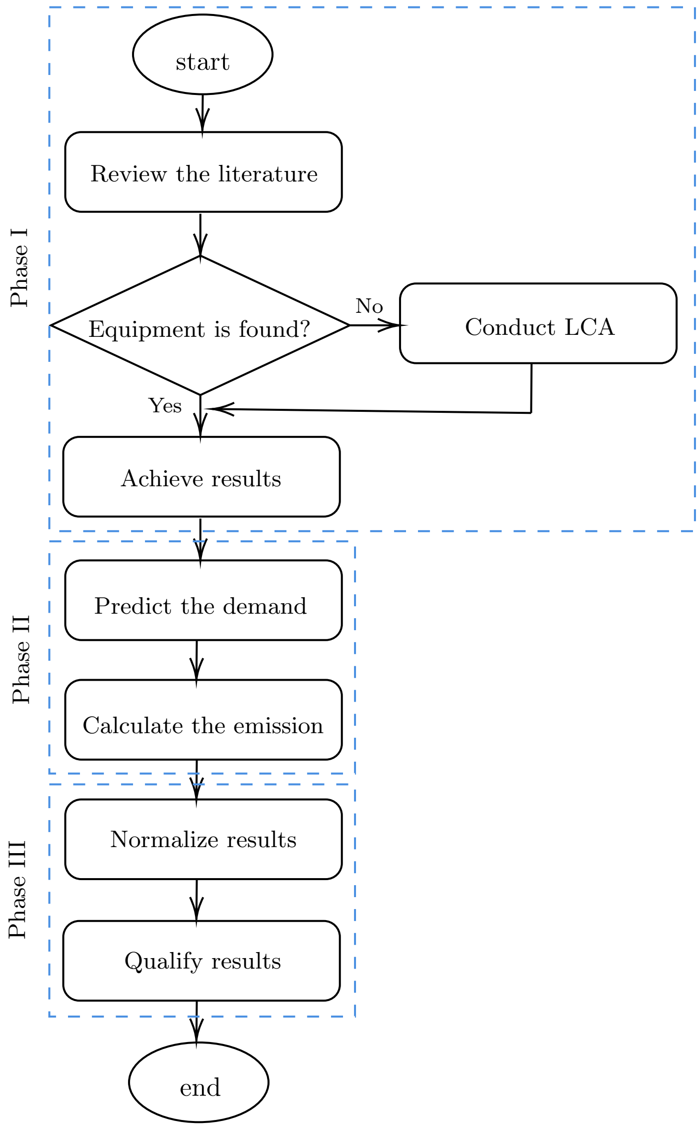


Figure 1: The framework of the sustainable procurement process.

3.1 Classifying Equipment (initial phase)

Before starting the evaluation process, we need to classify the equipment to have a fair comparison in terms of environmental impacts. Different countries and health-care organizations have used different classifications. For example, Canada's health-care system uses a risk-based approach to classify medical devices. This classification includes four groups, where Class I indicates the lowest and Class IV represents the highest level of risk. However, this classification would not work for environmental evaluation since it ignores the lifespan/lifetime of the equipment. That is the maximum period for which a medical device is intended to maintain to be used safely and effectively. Generally, the manufacturers are supposed to provide the lifespan of the product. However, since the equipment is frequently used far beyond its manufacturer-specified "useful life," this lifespan isn't always a deciding factor. In this regard, a prediction method (e.g., regression model, time series forecasting and neural network methods) can be used based on manufacturer recommendations and historical data to predict the lifespan. By having this data in hand, we can classify the equipment.

In this project, we classify medical devices based on their intended use duration into three categories as follows:

(i) Transient or single-use medical devices are designed for immediate, one-time use and are meant to be used for a very short period of time, such as during a single medical procedure. Examples of transient medical devices include disposable needles, examination gloves, and most wound dressings. These devices are typically discarded after a single use.

(ii) Short-term medical devices are designed for use over a period of days or weeks but not for extended periods of time. Examples of short-term medical devices include manual blood pressure cuffs, pulse oximeters, and catheterization kits. Depending on the manufacturer's design and intended use, these devices may be reusable or disposable.

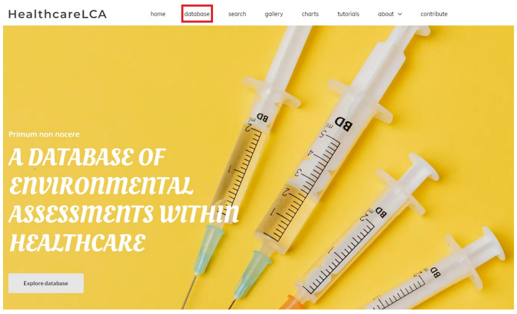
(iii) Long-term medical devices, also known as "durable medical equipment" or "assistive technology," are designed for use over extended periods, often for the patient's lifetime. Examples of long-term medical devices include wheelchairs, hospital beds, and oxygen concentrators. These devices are typically made from high-quality materials and are built to withstand the wear and tear that comes with regular use.

The idea behind this classification is that comparing consumables, including single-use and short-term, products like gloves with durable products like MRIs with a long lifespan is not practical. For example, based on VCH historical data, MRIs often last anywhere in the range of 13-21 years, while in this period, we may consume billion of gloves. Therefore, comparing the environmental impact of one unit of a single-use or short-term medical device with a durable one does not make sense. It is important to note that the use duration of a medical device can vary based on individual needs, conditions, and treatment plans. Patients and healthcare providers should consult with a medical device specialist to determine the appropriate type and duration of use for a specific medical device. Therefore, for future improvement, this classification can be updated.

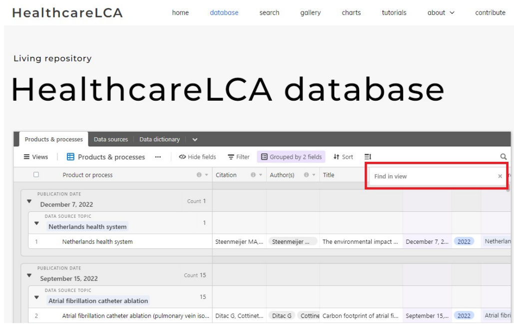
3.2 Literature Review (phase I)

Initially, the literature is reviewed to find the studies conducting LCA for given pieces of equipment. For this purpose, several web search engines, such as Google Scholar, Scopus, and Web of Science, are used. Moreover, there is an open-access database called HealthcareLCA collecting healthcare-related studies where the LCA is used for evaluating the environmental impacts of medical equipment. In this way, we found the studies that applied the LCA for our list of equipment and used the results of those studies in our analysis. If there is no study for a piece of equipment, the LCA can be conducted. In this phase, the results related to the environmental impact of equipment are achieved by reviewing the literature or applying LCA.

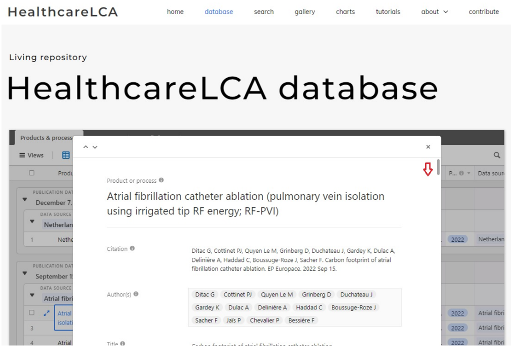
In the first step of this phase, HealthcareLCA is browsed to find all equipment in the equipment list provided by the EP team. Figure 2 shows the search process steps to find equipment in the database. First, we open the database and search for medical equipment. After finding a study conducting the LCA for the given equipment, we open it and scroll down to find its global warming potential per functional unit. This is a number we need for our evaluation. In this project, the kilograms of carbon dioxide ($kgCO_2$) is used as a unit for global warming potential impact. It is worth mentioning that some other impact categories (e.g., Ozone depletion potential and acidification) can be considered. However, most studies only addressed the global warming potential as an impact category. Therefore, we considered this category to simplify the comparison. The mentioned forecasting approaches (regression model, time series forecasting and neural network methods) can also be used for demand forecasting.



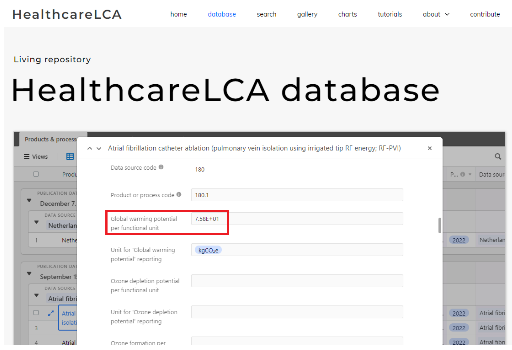
(a) Step 1



(b) Step 2



(c) Step 3



(d) Step 4

Figure 2: Browsing HealthcareLCA database.

3.3 Impact Calculation (phase II)

In this phase, the annual environmental impact of equipment is calculated using the results obtained from literature/LCA and the annual demand. The annual demand should be predicted based on the functional unit used in LCA. The functional unit describes a product or system's quantity based on its performance in its end-use application. For example, assume that the functional unit for an anesthesia unit is one hour of continuous operation of the anesthesia machine. To convert this unit to annual demand, we need the total duration of surgeries undergone during one year. Then, we can estimate the annual CO_2 emissions of the product. To better understand the functional unit, let's consider another example, the Hemodialysis machine. The functional unit could be one session of hemodialysis treatment, and the annual demand could be estimated based on the number of sessions performed in a year. This would enable a comparison of the environmental impact of different hemodialysis machines based on factors such as water and energy consumption, materials used, and end-of-life disposal.

This project uses a spend-based method to estimate the annual emission for Scope 3 categories related to healthcare industries. Scope 3 covers all indirect emissions that take place along a reporting company's value chain (for more information, interested readers refer to the United States Environmental Protection Agency). This method estimates produced emissions by multiplying the financial value of a product by an emission factor or emissions produced per financial unit. Equation (1) calculates the spend-based emission of product i where E is the spend-based emission factor, C is the unit price (\$) on the product, and S is the secondary emission factor per functional unit (global warming impact in this study).

$$E_i = C_i * S \tag{1}$$

For example, consider that the functional unit used LCA conducted for this product is one unit, producing 2 $kgCO_2$ per functional unit. Moreover, the annual demand for product i is 100 units, and the cost of purchasing one unit is 5\$. With this information in hand, the spend-based emission of the product is equal to $(5*100)*2 = 1000$.

3.4 Result Interpretation (phase III)

This phase determines the level of impact for each defined category. First, the results obtained from the previous phase are normalized since the impact scale could vary. Therefore, the results should be normalized to have a fair comparison. For this purpose, a linear normalization method is used, as shown in Equation (2). In this equation, x' is a normalized value of x. x_{min} and x_{max} are minimum and maximum numbers among the dataset, respectively.

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{2}$$

In the next step of this phase, the normalized data should be qualified to provide the EP team with a term indicating the level of impact. To do so, a box plot that shows a data set's five-number summary, including the minimum, first quartile, median, third quartile, and maximum, is used in this study. Figure 3 shows an example of a boxplot. Using this plot, the equipment can be classified into four levels, where Level 1 indicates the lowest and Level 4 represents the highest level of global warming impact.

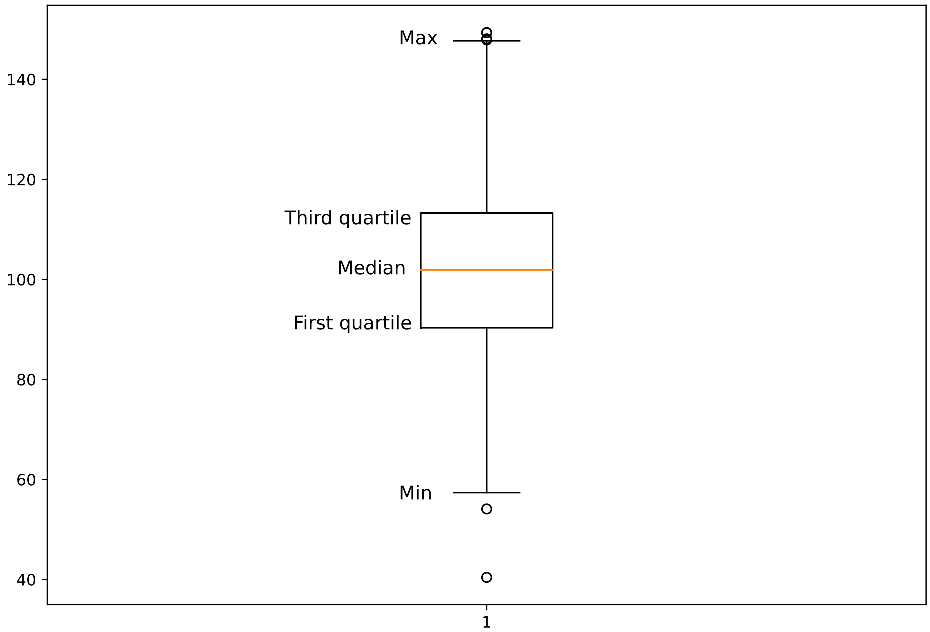


Figure 3: An example of the boxplot.

3.5 Numerical Example

To show how the proposed framework works, a small-size example is defined in this section. Let's consider ten medical devices named E1 to E10. Annual demands, unit prices, and emissions ($kgCO_2$) are randomly generated using uniform distribution in the range of $[10, 50]$, $[5, 10]$ and $[1, 5]$. The values of parameters for each device are reported in Table 6.

Table 1: The randomly generated data

Name	Demand	Unit price	Emission
E1	49	10	3
E2	43	5	1
E3	47	12	2
E4	24	5	1
E5	47	10	5
E6	42	13	1
E7	12	12	5
E8	43	5	3
E9	13	5	2
E10	17	10	2

After collecting the required data about each device, the global warming impact can be calculated using Equation (1). Then, these values are normalized using Equation (2). Finally, using a box plot shown in 3, the impacts are classified into four mentioned levels to qualify the environmental impacts of each device. Table 2 shows the results of this example. From this table, one can notice that most devices have a low inverse environmental impact, and there are two high-level devices (E1 and E5).

Table 2: The results of the given example.

Name	Impact	Normalized impact	Level
E1	1470	0.605	4
E2	215	0.043	3
E3	1128	0.452	3
E4	120	0.000	1
E5	2350	1.000	4
E6	546	0.191	2
E7	720	0.269	2
E8	645	0.235	2
E9	130	0.004	1
E10	340	0.099	1

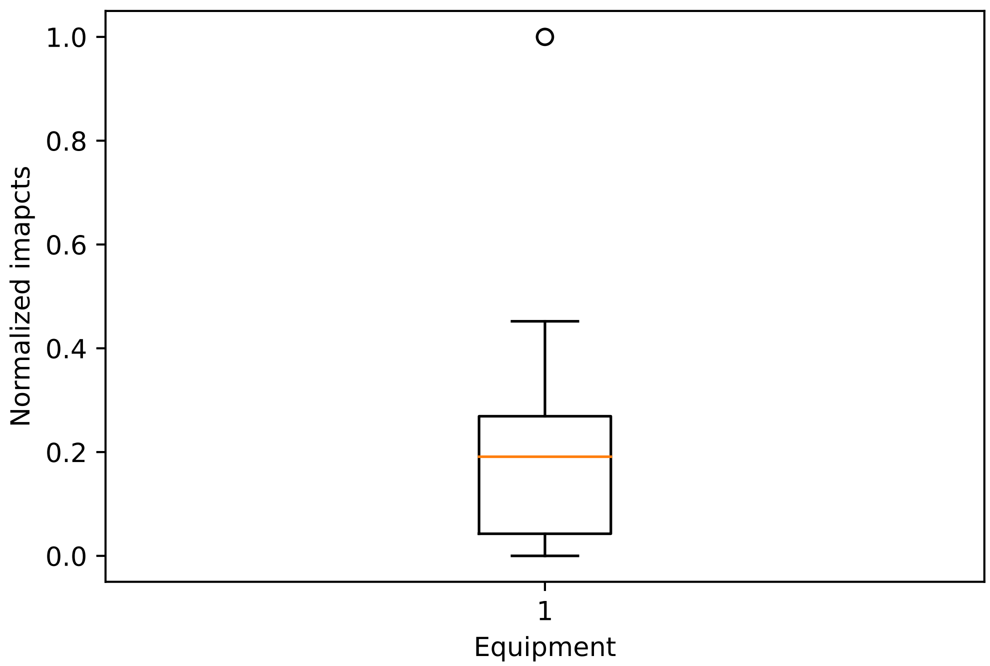


Figure 4: The results of normalized impacts.

4 Results and Discussion

This section first provides an overview of the information obtained from our literature review on the environmental impact of the list of medical devices. The primary purpose of this section is to present the information in a clear and organized manner, making it easy for the reader to understand and calculate the environmental impact of different devices.

The initial results of the literature review are summarized in Table 3-5 for single-use, short-term and durable devices, respectively. These tables include the name, description and the types of the given device considered in that study. By types, we mean the different kinds of devices that were included in the study, such as the Anesthesia Unit which was evaluated at various flow rates (2L/min, 6L/min, 8L/min, and 18L/min) with a fixed fraction of inspired oxygen ($30\% FiO2$) to compare their life cycle assessments. It is important to note that not all devices have multiple types associated with them, and some devices may simply be described without further categorization.

To make the comparison simpler, we assign a label for each device. In this regard, S, ST, and D stand for single-use, short-term and durable, respectively. The first number is assigned to separate the devices and the second number is for identifying the type of each device. For example, D1-1 stands for the first type of first durable device, which here is 1L/min of Anesthesia Unit.

Table 3: Single-use equipment list.

NO.	Equipment	Description	Type
S1	Bronchoscope	Ambu® aScope	Disposable
S2	Sharps container	–	Disposable

Table 4: Short-term equipment list.

NO.	Equipment	Description	Type
ST1	Bronchoscope	Cleaning and sterilization	Reusable
ST2	Sharps container	–	Reusable

Table 5: Durable equipment list.

NO.	Equipment	Description	Type
D1-1	Hemodialysis	Hemodialysis CRRT Unit Hemodialysis Unit, Portable	in-center, 3x4hr treatments/week with standard machine
S1-1	Anesthesia Unit	Fresh gas flow, Dräger Primus anesthetic machine	1L/min (30% FiO2)
D1-2			2L/min (30% FiO_2)
D1-3			4L/min (30% FiO_2)
D1-4			6L/min (30% FiO_2)
D1-5			18L/min (30% FiO_2)
D1-6		Fresh gas flow, GE Aisys CS_2 anesthetic machine	1L/min (30% FiO_2)
D1-7			2L/min (30% FiO_2)
D1-8			4L/min (30% FiO_2)
D1-9			6L/min (30% FiO_2)
D1-10			18L/min (30% FiO_2)
D2-2			in-center, 4x4.5hr treatments/week with standard machine
D2-3			at home, 5x4hr treatments/week with standard machine
D2-4			at home, 6x2hr treatments/week with standard machine
D2-5			at home, 6x7hr treatments/week with standard machine
D2-6			at home, 3x7hr treatments/week with standard machine
D2-7			at home, 5.5x3hr treatments/week with NxStage System One machine
D2-8			at home, 6x7hr treatments/week with NxStage System One machine
D2-9			in-center, 3x4hr treatments/week with standard machine re-used over 10 treatments
D3-1	Nebulizer	Radioactive Technetium/Carbon Particle	electric nebulizer cleaned in dishwasher
D3-2	Oximeter	Pulse oximeter	
D4	Phacoemulsification	Cataract surgery	

Table 2 presents the quantitative input data that is necessary to calculate the spend-based emission factor. Specifically, the table provides information on the global warming impact of each device. This impact is expressed in kilograms of carbon dioxide equivalent ($kgCO_2e$), which is a measure of the potential impact that the device has on global warming. The "Functional Unit" column in the table provides information about the unit that is used to evaluate the environmental impact of each device. This unit could be a specific amount of a product or a certain process used in the manufacturing of the device. For instance, if the table pertains to the production of steel, the functional unit could be one ton of steel. The "Global Warming Impact" column in the table provides information on the $kgCO_2$ that are emitted during the production or use of each device.

Table 6: Input data.

NO.	Functional unit	Global warming impact ($kgCO_2$)
S1-1	One hour of continuous operation of the anesthesia machine (with FiO_2 of 30%).	$1.30e-01$
S1-2		$1.30e-01$
S1-3		$1.20e-01$
S1-4		$1.40e-01$
S1-5		$4.00e-01$
S1-6		$1.40e-01$
S1-7		$1.30e-01$
S1-8		$1.30e-01$
S1-9		$1.40e-01$
S1-10		$3.30e-01$
ST1	Use of one bronchoscope	$2.90e+00$
S2		$1.60e+00$
S3	Provision for 100 occupied hospital beds for one year	$2.42e+04$
ST2		$4.00e+03$
D1	One kilogram of bodily fluid collected during elective surgery	$1.25e+04$
D2		$4.50e+02$
D3	One year of treatment for one patient	$3.82e+03$
D4		$4.35e+03$
D5		$5.12e+03$
D6		$5.21e+03$
D7		$7.20e+03$
D8		$3.90e+03$
D9		$1.84e+03$
D10		$2.13e+03$
D11		$3.45e+03$
D12	Delivery of 1 dose of inhaled medicine	$2.94e-02$
D13		$4.77e+03$
D14	One item	$5.23e-02$
D15	One procedure	$8.11e+01$

To calculate the spend-based emission factor, we need to know the annual demand for the device in question, converted to the functional unit used to evaluate its environmental impact, as well as the amount of money spent on purchasing one functional unit of the device. However, obtaining this information can be a time-consuming and complex process.

Therefore, to provide a practical example and clarify the method, we used randomly generated demand and the available unit price to estimate the spend-based emission factor. It's important to note that the results of our spend-based emission factor calculations using randomly generated demand may not be entirely reliable. The demand figures generated in this manner are not based on any real-world data or predictions, and as such, may not accurately reflect the actual demand for the device in question.

The use of randomly generated demand was a decision made due to the lack of available data and limited time for data collection during our project. while our approach was a necessary first step, it is recommended to gather more accurate data in the future to ensure the reliability of the spend-based emission factor calculations. Therefore, it is important to acknowledge the limitations of our methodology and the potential inaccuracies of the results. Further research and data collection will be necessary to obtain more accurate figures for the demand and spend-based emission factor of the device in question.

The results are reported in an excel where detailed data and results of proposed spend-based emission factor calculations are provided. The impact was calculated based on the randomly generated demand, unit price, and global warming impact obtained from the HealthcareLCA database. We have further classified each category (single-use, short-term and durable) into four impact levels, ranging from low to high. In addition, we have ranked the devices by each category and by all devices to provide a better understanding of their environmental impact relative to each other. This information can be useful for identifying areas where improvements can be made and developing strategies to reduce the overall environmental impact of the healthcare industry.

5 Conclusion

To summarize, this project developed a framework to evaluate the environmental impact of equipment purchasing by the EP team of VCH. The framework consisted of four phases: classifying equipment, literature review, impact calculation, and result interpretation. The developed framework can assist the EP team of VCH in making informed decisions that contribute to sustainability. The framework's strengths include the classification of equipment based on its intended use duration and the use of the spend-based method. It is important to acknowledge the limitations of our methodology and the potential inaccuracies of the results. Future research and data collection efforts will be necessary to obtain more accurate figures for the demand and spend-based emission factor of devices. Nevertheless, the results of the spend-based emission factor calculations are reported in an excel sheet, where detailed data and results of proposed calculations are provided. The impact was calculated based on the randomly generated demand, unit price, and global warming impact obtained from the HealthcareLCA database. The results provide a clear understanding of the environmental impact of devices classified into each category and ranked by all devices, which can be useful for developing strategies to reduce the overall environmental impact of the healthcare industry.

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