CASE STUDY

"Knowing the facility first" – Analysing environmentally relevant structures and processes in hospitals: A case study

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ABSTRACT

The operation of hospitals creates significant environmental burdens due to their large energy and material requirements, in addition to their production of hazardous wastes. Past research has predominantly focused on the role that medical technology and building design have on the environmental impact of hospital operations. In this paper, a holistic framework is developed to analyse hospital operation in order to better understand the processes, employee behaviours, and structures which contribute to the environmental impact of hospital operation. Specific focus is put on the derivation of a simple but effective method, which can also be applied by non-medical and non-specialized consultant personnel in general clinical contexts. Through the use of three empirical pathways, the employee perspective, patient perspective, and building perspective, data was gathered via a case study of the Children's Hospital (CH), Medical Center, University of Freiburg, Germany. Results revealed linkages between specific employee processes and the consumption of energy and materials, as well as potential pathways for future sustainability relevant monitoring. Characteristics of the hospitals administrative organizational and operational characteristics highlight the difficulties in gathering pertinent data for a complete analysis. Insights, in particular regarding employee behaviours, provide avenues for future research to better understand the implementation of sustainability programs in hospitals.

Key Words: Hospital sustainability, Hospital operations, Environmental impact, Facility management

1. INTRODUCTION

In most developed countries, an ever-increasing share of national gross domestic product (GDP) is spent on healthcare, which in turn uses a significant, but as of yet unclear, proportion of the world's natural resources - including water, minerals, food and oil. The delivery of healthcare services thus contributes substantially to total CO_2 emissions and in turn to the deleterious effects of climate change. Healthcare is responsible for over 3% of England's and 8% of the United States' total CO_2 emissions.[1,2]

If the contribution to these environmentally damaging effects is tied with an organization's sustainability, it is thus of concern for such organizations to understand how their characteristics and design influence this metric. As stated by Funk, a sustainable organization is one "whose characteristics and actions are designed to lead to a 'desirable future state' for all stakeholders".[3] A desirable future state in this regard is one which limits the contributions to the negative

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outcomes of climate change. In the context of a hospital, achieving this latter point is quite difficult. Few settings are more difficult to design and operate for sustainability than hospitals due to their critical functions, continuous operation, substantial demands for water, production of various wastes and constant energy consumption.[4]

Past research has explored hospital design, direct energy consumption, water procurement, waste, travel, as well as psychology and behaviour.[5–10] A meta-analysis carried out by McGain & Naylor found that research concerning architectural and design factors of hospital buildings is at a relatively mature stage.[2] Similarly, research regarding devices and technologies used within hospitals has also been carried out in a high percentage of studies.[2] Less is known about the clinical, psychological and social factors that influence how health care professionals utilize resources, interact with the technologies available and travel to and from their workplaces.[2]

Research investigating the architecture of medical facilities found that the initial capital costs of a hospital building represent less than 10% of the full lifetime costs. Operating costs, and especially energy usage, are the pre-dominant contributors to the lifetime costs of a hospital; this indicates the importance of incorporating energy efficiency at the planning and design stages.[2, 11] Modelling of direct energy usage in large buildings, such as hospitals, has stimulated research into specific technologies such as gas-fired co-generation, solar thermal cooling and ground-sourced heat pumps. Co-generation in particular has been found to be ideal for hospitals which require both continuous electricity and heat. Additionally, their self-generation provided the added benefit of energy security.[12] Further research in the area of building design has highlighted potential conflicts between healthcare services and building energy usage within hospitals. An often cited example in the literature involves the use of single patient rooms due to their associated reduction in infection rates. However, such rooms also incur additional upfront costs and energy requirements compared with their multi-use alternatives.[2, 13] Contrarily, implementing water saving measures has little consequence on the delivery of health services; and can result in water-use savings of 10%-25% via simple means (e.g., data logging meters, submetering, checking for leaks, and applying flow restrictors on hand basins and showers).[14]

Research efforts investigating the operating costs of medical equipment have been hampered by the incomplete information for many machines as they are actually used within hospitals (e.g., sterilizers, anaesthesia equipment).[1] Associated costs of such equipment, such as consumables required for their operation, have been sporadically researched – partially due to barriers from the medical industry itself. Research by McGain et al. found such impediments by industry partners who did not wish to create controversy around their products (i.e., the commercial implications of comparing products and processes could suggest "winners and losers" in their industry area).[15] Despite these difficulties, the aforementioned research indicated that anaesthetic gases alone have the same global warming potential as one million American passenger cars.[15] This impact represents one area of support, and the general importance of continuing medical product research to better understand the environmental impacts of their operation and use.

While some themes were investigated prolifically in past research (e.g., sustainable architecture has an extensive research base including textbooks with hundreds of references and standards focussed specifically on healthcare),[2, 4, 16] others such as psychology and behaviour have been less explored. Nonetheless, preliminary research has shown that, in the case of recycling habits, personal interest in environmental well-being was found to increase the likelihood that employees would recycle at their hospital. However, not all environmentally sustainable personal behaviours are carried into the workplace (e.g., willingness to recycle is sometimes hampered by inadequate waste-diversion systems within hospitals).[17] The ramifications of behaviour change can be great - Masino et al. found that altering behaviour regarding modes of travel, or substituting travel with other modes of communication such as teleconferencing, could substantially reduce the CO_2 emissions and costs associated with these activities.[6] It is thus pertinent to investigate the relationship between employee behaviours and the capacity of their workspace to facilitate them.

Additional research has brought together both sustainable aspects of a hospital's operation and its strength in the delivery of quality medical care. Through the implementation of actions towards "greener" hospitals, safety and quality in the delivery of care can be improved, costs can be saved and staff motivation can be promoted.[18] Further, sustainability initiatives in the healthcare context, such as energy efficiency improvements and the sparing of resources, have been linked in with quality management - thus optimizing patient care and profitability in concurrence with improvements in sustainability.[19]

A comprehensive understanding of sustainability fundamentally corresponds to the medical ethos, which includes not only disease control and health restoration, but also the prevention of pathogenesis through maintaining the natural environment as the basis of human health as a whole, including

the maintenance of social relationships.[20] As Jamieson et al. state "[a]s climate change has become a certainty, so too has the need for the health sector and health professionals to anticipate, manage and ameliorate the burdens climate change will impose, and acknowledge that the health of populations depends on a successful transition to sustainability".[21] Many clinics are therefore very open to comprehensive sustainability management. However, they often lack the necessary financial, organizational and institutional resources as well as the specialized knowledge of sustainability in day-to-day business in order to be able to formulate a sustainability strategy as a basis for comprehensive sustainability management.

The aim of the research was to develop and test a relatively simple and quickly applicable method to analyzing the environmentally relevant structures and processes within Hospitals as basis for the development and implemention of comprehensive sustainability strategies. To keep extra efforts low and thereby increasing the likeliness of its application in a broad range of clinical contexts, the method should be also applicable by non-medical and non-specialized consultant personnel. The research aim and its specification led to three main research questions: (1) How to identify and link relevant areas in a hospital concerning sustainability? (2) How to find an approach for analysing and evaluating the sustainability performance of a hospital? (3) Which strengths and weaknesses result from the implementation of the identified approach within a practical case?

In order to answer these research questions, the paper is structured as follows: In the following section, a conceptual model will be introduced which draws from multiple specialized models of hospital performance and functioning as they relate to sustainability. Section three introduces the methodology, and in particular discusses the triangulation of various observational perspectives to create a comprehensive overview of a hospitals operation. A case study, the Children's Hospital (CH) in Freiburg, Germany, is introduced to provide an investigative pathway to apply the conceptual model and method. In section four, results from these different perspectives will be presented. Section five provides a reflection on the effectiveness of the employed conceptual model and method. Lastly, section six discusses the ramifications of the results and suggests pathways for future research.

2. Conceptual model for analysing a hospital's sustainability performance

The previously cited research highlights the complexity of hospitals and the need to investigate multiple facets of their operation, i.e., ecological, economic and social, to better understand current levels of sustainability and potential pathways for sustainability improvement. In this way, the desired outcome of health can be seen on the one hand as a result and on the other hand as a precondition for sustainability.[22] Hospitals thus need an approach to face these sustainability expectations in an integrated way, as outlined in Figure 1 below.

<table>
<tr><th colspan="3">Health</th></tr>
<tr><th>Economy</th><th>Ecology</th><th>Social</th></tr>
<tr><td rowspan="3">Economic and business longevity</td><td>Climate protection</td><td>Fair access to services</td></tr>
<tr><td>Biodiversity protection</td><td>Fair access to career and promotion opportunities</td></tr>
<tr><td>Resource protection</td><td>Distributive justice and poverty reduction</td></tr>
<tr><td>Competitiveness</td><td rowspan="2">Ecological agriculture</td><td rowspan="2">Improving the quality of life</td></tr>
<tr><td>Exchange of knowledge/innovations</td></tr>
<tr><td rowspan="2">Integrity and transparency</td><td>Water protection</td><td>Participation</td></tr>
<tr><td>Environmental protection</td><td>Protection and safety</td></tr>
</table>

Figure 1. Sustainability expectations under the overall theme of health - own representation

Bodemeyer et al. highlight three levels of improvement in medical patient care and economic efficiency in the context of hospitals in their "Blue Hospital Concept".[23] The technological basis (e.g., building and energy technologies), can be found on the lowest level. These make up a range of technologies which are necessary to provide quality patient care and economic performance. Processes and services make up the second level in a hospital, and include items which can be improved in terms of their quality of outcome (the highest level). In regards to the term Blue Hospital, Bodemeyer et al. describe the concept as concealing the synergistic relationship between ecology, economy and efficiency with the well-being of humans, which correspond to the aforementioned sustainability expectations for a hospital.[23] The included structures and processes provide focus for the use of demand analysis and assessments to optimize the delivery of products and services. Assessments include the analysis of material and energy consumption as well as room functions and usage.[23]

From the level of the Blue Hospital Concept, the following hospital areas were taken into further consideration: process management, supply chain management, facilities management, and information technology management.

Concerning process management in hospitals, Gadatsch provides a comprehensive model.[24] It delineates management processes in a hospital, creating subcategories of planning, governance and monitoring. Such processes may be considered universal for each hospital, as they are sufficiently broad to capture the activities taking place while still providing some specificity. Primary processes encompass the core medical processes, such as care and medical support, while supporting processes include information technology and facility management.[24]

The combination of Gadatsch[24] and Bodemeyer et al.,[23] resulted in the overall model presented in Figure 2. This framework not only focuses on the four areas in hospitals mentioned above, it also contains the persons that are part of these processes and thereby differentiates between staff and patients. In addition, the produced overall model is relatively abstract and therefore generalizable, allowing it to be applied to different types of hospitals.

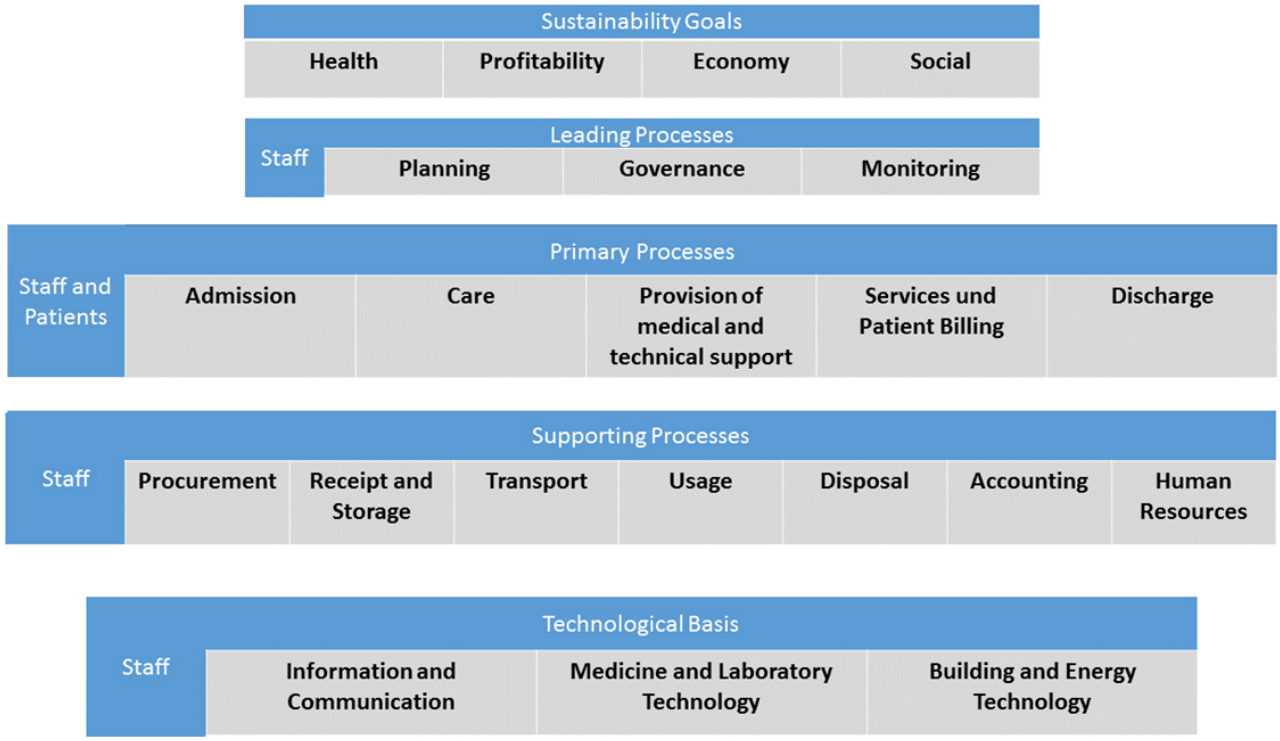

Figure 2. Overall model of hospital in the context of sustainability – own representation

The first level, which forms the basis of the overall model of a hospital in the context of sustainability, includes the specifically defined sustainability goals: "Health", "Economy", "Ecology" and "Social". Remaining levels refer to the processes within a hospital that are hierarchically structured. Thus, the second level includes the leadership processes that affect both the primary and support processes as well as the technological base. However, the various levels principally

affect the primary processes, as these are the core functions of patient care in a hospital. The third level includes all medical and nursing processes and is supported by the fourth and fifth levels. This support is provided both administratively by human resources and accounting, as well as by goods and materials - which are coordinated from the procurement process along the chain of use to disposal. Ultimately, leadership, primary and support processes are complemented by the technological base. In particular, medical and laboratory technology serves the described primary processes, and information and communication technology is used both for planning at management level and for accounting at the support level. Thus, there are various interactions and overlaps between the individual levels as the involvement of staff and patients varies. However, these interactions are complex and unique according to the hospital being analysed. Depending on penetration with, for example, information and communication technology, the administrative processes may still be implemented manually or through the use of technology. Due to these potential differences, more detailed investigations of the individual case in the planning and implementation of sustainability projects are still useful and necessary despite the comprehensiveness of the overall model. This notwithstanding, the conceptual model serves as an aid in locating and analysing various relevant processes and areas of improvement within a hospital.

3. METHOD – TRIANGULATION OF OBSERVATIONS

In order to evaluate the sustainability performance of a hospital regarding the identified areas in the conceptual model, three perspectives (triangulation) need to be taken into consideration: the employee perspective, the patient perspective and the overall room perspective. These perspectives focus on the users of the hospital building and the conditions given by the hospital building.

The employee perspective focuses on the sustainability performance of the employees and their attitude towards sustainability. It includes the actions employees take for sustainability, e.g. by recycling or saving electricity by switching lights off. By understanding a typical day of an employee at the hospital, the overall sustainability performance of this employee can be described. Therefore, an observational method was chosen. Hospital employees were categorized into three groups: nurses, doctors and other employees such as cleaning personnel and administration. For each of these groups, ideal-typical practices were developed through literature research and experts from the field. These practices represented recurring tasks of each employee group. During the observation, each practice was assigned duration, the energy and water used to perform the practice, waste produced, other employees or patients involved in the practice and the equipment needed. An employee observation resulted in a pattern of practices performed. As the observations focused on gathering data of sustainability performance, semi-structured interviews about sustainability expectations were held with employees to examine their understandings of sustainability as a concept.

The room perspective concentrates on the given circumstances within hospitals that the users, employees and patients have to cope with. Therefore this perspective views the room as is, and evaluates its contents and spatial arrangement. The observers observed the deserted room, inventoried everything in it and checked for air quality, energy usage and waste disposal. The objective of these observations was to support the employee observations through an inventory and accounting of the circumstances of building design for the employee practices. Furthermore, a multi-regional input-output model was developed in order to intersect the generated data from room observations with the calculation of the carbon account, as measured by net greenhouse gas emissions along the supply chain of products and energy, for the consumption of the hospital.

The patient perspective focuses on the influence patients have on the sustainability performance of a hospital. Observations were not possible in this case due to privacy concerns. Instead, a questionnaire was designed.

Utilizing three observational perspectives is designed to reveal synergies for the implementation of sustainability within a hospital, and will therefore be applied to a case study. In addition to the Blue Hospital concept, which cites synergies between different operating areas of a hospital as they relate to sustainability,[23] this assumption is supported by the structure of the overall model, which places a requirement on acquiring data from not only the hospital building itself, but from its use by both employees and patients.

3.1 Introduction of the case: Children's Hospital, Medical Center, University of Freiburg

To better understand the efficacy of the constructed conceptual model in describing the sustainability of a hospital, a case study was utilized investigating the CH in Freiburg, Germany, a paediatric hospital at the Freiburg University Medical Center. The CH consists of various building complexes from the 1960s, 1980s and one building from the 2000s. At the CH, approximately 7,000 patients are admitted each year, with patients admitted to the inpatient service staying on average 4 to 5 days. The mixed building structure complicates the work of the employees because most rooms

were created during a time when the hospital culture was different and less technical equipment was needed. Due to this, most of the rooms are crowded with equipment. Therefore, the CH has launched an initiative for relocating to a new hospital building which will be sustainability certified with DGNB Platinum.

In order to get a feeling for employees' perspectives on sustainability a quick survey was carried out in the beginning. A total of 13 employee surveys were completed, of which 8 were completed by nurses, 2 by doctors, 1 by a nurse in training, 1 by an educator and 1 by an employee responsible for sanitation. The greater percentage of nurses in this sample is attributed to their foreknowing of this project and their eagerness to participate in sharing their views - they thus made themselves more available. Given the non-representativeness of the sample in conducting these surveys only generalizable insights were gathered.

Inquiries into what employee expectations were for sustainability yielded mentions of materials (8 persons) and food consumption (6 persons), room ventilation/tempering (5 persons) and waste separation (4 persons). Ecological themes were predominantly cited, with only a few respondents mentioning social and economic sustainability aspects (e.g., consultation with employees (4 persons), respectful working conditions (4 persons), and stress reduction.

As expected, employees in general have an extremely busy schedule and feel overwhelmed with time consuming documentation requirements – which contributes to why openness to written or oral surveys is very low. In order to understand the sustainability performance in the hospital processes from an employee perspective, the decision for implementing an indirect assessment through "shadowing" observations was made.

In order to perform the observations, two representative areas within the paediatric hospital were chosen: one emergency ward and one ward for inpatient care. The general emergency ward area is designed for outpatient services and is located on the ground floor of one of the hospital complex's buildings. This area is specialized for high patient-traffic and utilizes a triage system to organize its services. This organization means that a prioritization of the diagnosis based on urgency takes place and a subsequent allocation of patients to respective departments is made. The inpatient ward named Moro, in contrast, is located on the second floor and specializes in inpatient services. This ward experiences lower patient traffic and contains a population which will remain in the hospital for a longer period of time due to the provisioning of specialized services (e.g., rehabilitation, long-term treatment, etc.).[25]

3.2 Observations within the CH

In line with the focus on derivation of a simple but effective method, which can be also applied by non-medical and non-specialized consultant personnel in general clinical contexts, the observation team was comprised by six graduate students from study backgrounds in the area of social and environmental sciences. Three of the observers were non-native German speakers. The observation team was given a brief background on medical instruments and machines most commonly used in hospitals as to better equip them for identifying such devices. Software equipped Ipads provided the observation team with an electronic means of cataloguing employee behaviors and room observations.

Observations were carried out throughout the main operating hours of the hospital clinics, from 8:00 a.m. to 5:00 p.m. (when out-of-home medical services, pedagogical and psychological care as well as day care are available).[25] Time periods of observation were selected in order to obtain the broadest possible picture of the processes in the field. Observations were made to be as representative of actual operations as possible (e.g., a whole shift), as well as for special situations (e.g., change of shift and food distribution). These passive observations of processes were carried out by employee groups (i.e., nurses, doctors, and other), which included their interactions with patients and colleagues. They were guided by a process inventory created to provide data on such areas as waste disposal, time spent with patients, processes utilizing electricity, and movements by staff around the hospital. An additional short guide-based interview, comparable with situational adjusted informal conversations, was given to employees.

In addition to these group specific observations, observations were also carried out in hospital rooms empty of patients and staff to inventory the equipment, energy and material usage of the hospital (thus, all three aforementioned perspectives were accounted for). Both employee observations and room observations were carried out utilizing digital equipment with an inventory and process database loaded so that observers could easily input data into a central database from which analysis could be carried out.

In order to gain insight into the patients' perspective of hospital operation and sustainability a questionnaire was utilized. This area of inquiry, titled Little Researchers, included questions suitable for children between the ages of 6-15, and was made available in 5 major languages (German, English, Turkish, Arabic and Russian). The questionnaire was designed around the overall aim of education for sustainable development and also provided information on how to improve sustainability performance. Employees at the main

information desk were instructed to give these questionnaires to patients, when suitable, to be filled in.

4. RESULTS

4.1 Employee and room perspective

A total of 37 rooms were inventoried during this study, with 4,326 minutes of activity accounted for within the observation scheme. Within these activities, 38 individual processes were accounted for - totalling 980 process instances. Of this total, 411 processes were attributed to nurses in the Emergency room, 337 to nurses in the Moro ward, 143 for doctors (54 in Moro and 89 in the Emergency ward), and 89 to the other employee type.

4.1.1 *Process management*

Process management yielded insights into the time spent by various employees on certain processes. Differentiating processes concering material usage and waste production as well as energy consumption in regard to IT can have a relevant function for the indication of leverage points in order to facilitate efficiency improvments and waste reductions. Task intensity, i.e., the amount of time attributed to specific processes, differed between employee types, e.g. nurses spent 16.5% of their time with documentation tasks as one of their main tasks, while doctors spent 26.3% of their time on patient-related documentation, 17.8% on consulting and clarifying tasks and 14.9% on visiting patients in their rooms. The other employees mostly cleaned (58.3%), performed other tasks (34.0%) or were occupied with waste disposal (7.0%). Of note, nurses had the greatest diversity of task types attributed to their activities, with 28. Doctors and other employees were observed carrying out 12 and 4 process types respectively. This method for analysing the process management of a hospital yielded insights into patterns in employee processes.

Calculating time spent with colleagues and patients was made possible by coding for interactions between employee types. Doctors spend most of their time with fellow team members in general, of which almost 96% of the time is spent with nurses, and only 4% of the time with other employees. Nurses spend most of their time with patients or by themselves, and spend only 26% of their overall time with doctors. This indicates that doctors seem to need to collaborate more with nurses as part of their regular tasks than nurses need to with doctors.

These results of the study indicate that nurse and other employee processes are key in identifying sustainability potentials concering material usage as nursing and other employee tasks show a great diversity in handling materials, whereas processes attributed to doctors can provide insights into IT usage patterns as the highest share is attributed to computer related documentations.

4.1.2 *Purchases and supply management*

Financial data was to be inputted into a multi-regional input-output model in order to calculate the carbon account. Unfortunately, breaking down the financial figures necessary for such an analysis from the Freiburg University Medical Center to the organizational unit of the CH turned out to be a complex and time-consuming task. The Freiburg University Medical Center lists almost 50 sub-units like the CH on its website. At the same time the accounting system is not designed for sustainability management queries. For this reason financial data was not received and thus the carbon accounting operation was not completed.

4.1.3 *Facilities management*

Data related to the management of both Moro and Emergency ward facilities was collected regarding room usage, sources of noise, climate and comfort as well as energy usage.

In regards to room usage, the data yielded insights into whether designated room functions and actual use of the room were identical. With few exceptions (e.g., storage areas in used washrooms), this was mostly the case.

The observations of the noise within the hospital rooms showed the various sources of noise. Most identified sources were busy corridors and open windows.

The atmospheric quality of the rooms was registered to provide an insight into climate and comfort levels. Rooms designated as “stuffy” and “very stuffy” were attributed to poor ventilation systems and/or sterilizing and plastic odours. Poor ventilation systems in this regard referred to the lack of open windows and/or heating/cooling ventilation ducts which would have allowed for the circulation of fresh air into the rooms. These particular rooms did not fit into a specific use or function case. Indeed rooms rated as “stuffy” or “very stuffy” included administrative areas, storage closets and x-ray rooms.

Regarding the energy usage, little information was gathered through the observation data. One finding was that doctors’ energy consumption mainly includes computer usage while nurses’ energy consumption contains a greater share of energy consumption by medical machines.

4.1.4 *IT and medical technologies management*

Through the analysis of practices of the employee groups, the only statement regarding IT and medical technologies management to be made concerns their usage of computers. The majority of practices (> 75%) did not include computer usage. However, for those that did, doctors were found to have a much higher proportion (67.4%) when compared to

nurses (10.7%). The majority of computer usage by doctors was related to patient documentation.

IT infrastructure, cable routing or communication interfaces were not recorded within the observations and therefore little findings were gathered concering Green IT sustainability practices. According to Murugesan, one single computer produces about a ton of carbon dioxide every year.[26] Therefore, Murugesan argues that the implementation of an environmentally sound IT requires the "[. . .] design, manufacturing, using, and disposing of computers, servers, and associated subsystems – such as monitors, printers, storage devices, and networking and communication systems – efficiently and effectively with minimal or no impact on the environment".[26] This also involves the implementation of sustainability practices regarding the reduction of energy consumption associated with computers, as PCs produce heat and require additional cooling, which in turn contributes to the total power consumption.[26]

4.2 Patient perspective

Little Researchers data yielded a total of 6 survey responses, all of which were completed by speakers of German. Unfortunately, due to the low number of surveys meaningful insights cannot be gained; however, certain responses do seem to indicate trends in the investigated areas of sustainability. In regards to wastes, it became clear that the most frequently mentioned waste products consist of paper, diapers and packaging waste, of which at the packaging waste could be a reducible size. A total of 4 out of the 6 patients did not eat their food, which according to information from all questionnaires was then disposed of.

In terms of energy, responses indicated that lights were for the most part used only in the evening or very early morning hours, and were under the control of the patients and the nurses. Thus, unnecessary lighting seemed to be minimized during the daylight hours (when natural sunlight could enter the rooms). Patients also mentioned electronic entertainment media as utilizing electricity. However, specifics were not always used and thus little can be drawn from this regarding the potential for reducing this energy usage. Water usage was mentioned to principally derive from hygiene related activities (toilet flushing, showering, washing hands, etc.). Patients did not mention there being unnecessary water usage from e.g., dripping faucets or leaking pipes.

General insights into hospital functioning and organization from the patients perspective included feedback regarding contact with medical staff, in which it was said that frequent contact existed and patients felt supported. Deficits in this initiative within the research project will be outlined in discussion section 5.2.

4.3 Summary of major observation findings

Looking within employee groups revealed a delineation of responsibilities between such groups, with observations indicating nurses were responsible for a greater share of direct patient contact, whereas doctors were involved with indirect, administrative and documentation-related activities. For purposes of saving material and avoiding waste, as already indicated being a major issue in the employee survey, the research suggests that the analysis of nurse and other employee processes is key in the identification of sustainability processes. However, this requires a comparision with hygenic and infection protection standards like compiled by Daschner or Dettenkofer et al.[27,28] These approaches address environmental concerns regarding the reduction of material and waste through the lens of changing and adapting procurement processes (e.g. establishing a procurement commission that overlooks purchases) towards achieving sustainability goals.

An area warranting further analysis is the impact of patient meals, and the food supply chain more generally, used to service the hospital. Research by Virtanen et al. carried out in Finland found that a single lunch portion served at an education campus was responsible for between 0.65 and 3.80 kg of equivalent CO_2 - and the food supply chain itself was responsible for 14% of all emissions in the country.[29] Given the number of meals served daily at the hospital it would be prudent for future research to investigate the food supply chain of the hospital - such research could yield insights into highly impactful changes in reducing the environmental impact of its operations.

While no conclusions could be drawn from a financial analysis of hospital consumption due to a lack of available data, some conclusions could be drawn from other observational data related to facilities management and energy and computer usage. In these regards, room function and use was found to be mostly congruent, with a few exceptions due to utilizing low-traffic spaces for storage. Atmospheric quality was found corresponding with the absence of ventilation. Finally, an energy usage breakdown between sources found that lights were the most of cited use of power - however the magnitude of this usage was not ascertained, again due to the limitations of the employed methodology. These points will be addressed in the following sections.

5. Reflections on conceptual model and methodology

5.1 Efficacy of the conceptual model

The role of the conceptual model was principally to identify relevant hospital areas regarding sustainability. Following

four principle areas of inquiry (i.e., economic, ecological, social and health), the model blended patient care with economic and environmental efficiency. In order to lessen the complexity of referencing the entire spectrum of processes and services in a hospital, subgroups were designated: purchase/procurement, finances, human resources, information technology and facilities management.

Acquired data from the observations revealed processes and potential sustainability measures which were not preconceived. In particular, the impact of food and movement of employees throughout the building provide new areas of inquiry - as does the further development of power consumption measures for gaining a more nuanced insight into the extent that medical equipment impacts energy usage at the hospital. These items can naturally be integrated into the utilized model, as it is relatively abstract and thus generalizable. Not only does this permit the expansion of methodological scope, but also allows the application of inquiry into different types of hospitals. Despite the comprehensiveness afforded by exploring the three perspectives of the facility not being fully realized due to methodological deficits, ultimately, the application of the developed conceptual model yielded insights into the analysed hospital facility, and thus provides avenues for sustainable interventions. The behavioural insights related to movement, waste disposal, and sustainability more generally provide an additional pathway which previous research has neglected. This important driver toward sustainable interventions is possible because human behaviour, the underlying driver of organizations, is reflexive, in the sense that people observe natural and social occurrences and modify their behaviour on the basis of this gained knowledge.[30] Insights gained through explorations of employee, patient, and facility attributes thus empower this reflexivity, and provide pathways for measuring and improving sustainability.

5.2 Methodological concerns

The CHs desire to practice sustainability provided an opportunity from which this study could be completed. Regardless of the building, machines and materials utilized (the hospital hardware) it was made evident that sustainability could be pursued with novel operating procedures and values (the hospital software). This was reflected in the methodology as well; which, though failing to provide fidelity regarding the usage of materials, equipment, or energy as desired, did provide qualitative insights which can strengthen future research.

The large effort put forth to conduct observations resulted in few empirical findings. However, the results do not fundamentally contradict the approach, but are mainly due to weaknesses in the implementation of the methodological design. Methodological deficits which contributed to this include a lack of reliability due to scheduling limitations - partly due to the limited time period for which data could be collected (2 weeks) and due to the limitations in coordinating observation schedules (e.g., scheduling two different observers for the same time period and individual). In order to gather as much data as possible among the different employee types, and across both hospital wards at the CH, observers were not scheduled for the same concurrent task. An additional deficit is in regards to the representativeness of the data itself - certainly so in the case of the observational data for the aforementioned reasons but also for the employee questionnaires, as the availability of employees for questioning was dependent on the employee and researcher schedules at the time of the study. Nursing duties and other tasks contributed to the greatest percentage of observational time in this study. This can likely be attributed to the share of time that different employee groups received - wherein nurses received the majority of observational resources. This also resulted in an overrepresentation of nurses for the interviews. This study would have benefitted from a much longer timeframe in order to better adapt to scheduling limitations and have a more representative sample of employees based on the employee population. Further, a longer time period would have afforded flexibility in coordinating observer schedules in order to ascertain the deviance in observations.

Additionally, the database utilized to input observed processes, including the usage and waste creation of various materials, was noted to be too limited in certain circumstances (e.g., gauging certain levels of computer or paper usage and waste disposal). There also existed certain limitations in determining the types of electronics or medical machines used (e.g., types of lights used in various rooms). This hampered efforts to more readily understand the potential energy usage in different areas and during different processes. Conducting a preliminary analysis in cooperation with the hospital employees could have alleviated some of the aforementioned deficits. The database could have been built according to the equipment and instrumentation present at the hospital, rather than through an analysis of what existed in hospitals more generally.

The results from the Little Researchers initiative highlighted some of the challenges of conducting research in a hospital setting. Distributing questionnaires to newly admitted patients was due to occur at the induction point for patients - however this was not always completed by staff. After clarifying with employees the directions for distributing the

questionnaire this area of the study was extended by two weeks; unfortunately the time extension did not result in more questionnaires being completed. In general, it can be assumed that this initiative was not prioritized by the staff, which is understandable given that the first priority for employees is to facilitate health-related activities at the hospital. Additionally, some young patients may be admitted to the hospital with various ailments which prevent them from filling out questionnaires; this, in combination with the often quick turnover times in the Emergency ward, prevented questionnaires from being completed. Nonetheless, results have shown that looking at the patient's perspective provides promising insights into hospital daily operations. Combined with the triangulation method of employee and room observation, it can reveal shortcommings in environmentally relevant structures in a hospital setting and the identification of relevant sustainability strategies. Therefore, from the expierence made within the CH, a possible suggestion for increasing the rate of completed questionnaries is to place questionnaires prominently in each ward and set up an information desk, e.g. by a person that feels responsible and has the time to provide information and motivation to patients regarding the completion of questionnaries.

Unfortunately, due to restrictions in the availability and organization of data relevant to conducting the material and energy flow analysis, this portion of the research could not be completed. The accounting system tracking the purchase of items such as medical materials, or water services, is controlled centrally within the Medical Center System. Despite the top-down approach in acquiring this data, current formatting of pertinent information such as where materials are delivered to and which hospital entities are responsible for their procurement was not made available. Thus, for many items an attribution to the CH could not effectively be made. However, it was found that for certain items the fluctuation of their use could be ascertained through other sources such as station managers (e.g., in the Moro ward). These items include disinfectants, towels, and protective clothing. As past studies have found that procured goods represent by far the largest contributor to healthcare's carbon footprint, exploring additional avenues of acquiring material and energy data may provide an important line of inquiry for future research.[2,31] The research suggests that conducting a material and energy flow analysis is a prerequisite for the methodological approach conducted in order to draw solid and reliable conclusions. A foundation set by such an analysis of procurement, augmented by observations of employee behavior and material and energy usage, would provide a much more holistic understanding of the environmentally relevant structures and processes in hospitals.

5.3 Knowing your facility first

Focusing on material and energy flow analysis from the perspective of hygenic and infection protection standards is nothing new, like seen on available literature discussing this topic such as Daschner.[27] In addition, the University Medical Center, like other hospitals, do have a special commission that deals with procurement issues in regard to environmental concerns. However, this is purley focused on a technical point of view, taking its departure from the product or material. Alternatively, concerning real-world implementations, it seems a much more promising avenue to start from working processes as emphasized in this research study, e.g. based on shadowing observations.

While both, conceptual model and methodological approach seem in principle well suited to analyzing the environmentally relevant structures and processes in hospitals, two fundamental requirements were missing: baseline and financial accounting data.

A baseline affords the opportunity for a reference point measuring change from a certain state or date.[32] Baselines are key should indicators be developed – which derive their utility as measures of progress and are important tools to decision making processes which aim to implement sustainability initiatives.[33]

There are two areas from which baselines can be developed for ameliorating the CHs environmental impact. The first relates directly with the observational scheme itself. This first study provided a trial of sorts for developing a more effective observation scheme from which to conduct future studies – and lends support toward a more iterative inquiry as data is collected and the organizational structure of the hospital is better understood. The aforementioned use of effective, refers to more accurately reflecting key measures of sustainability and, in general, accounting for aspects (e.g., paper usage) which were not properly accounted for in this study (though which would fall under the domain of the conceptual model). Additionally, this study provided a reflection point from which certain deficits can now be addressed (e.g., electronic equipment to lessen required physical movements around the hospital or seeking more comprehensive information to better understand what types of lights are actually used in individual rooms). Such initiatives would give a more nuanced understanding of the energy usage at the hospital - though they could of course be extended to include machines beyond lights, such as medical equipment power consumption measures, etc.

The second baseline area is in regards to the collected data. Should initiatives be put in place to track items such as task time or atmospheric quality, this study provides the first

measure from which future observations can be compared against, and thus tracked over time.

In connection to the first baseline area which this study provides, i.e., its role as a methodological test for measuring sustainability at the hospital, there are a number of items which were especially noteworthy to those involved with the study and which could help guide future research toward greater effectiveness. The first of these is in regards to the capacities of the observers themselves. These capacities range from knowledge of medical equipment - and thus the identification of equipment during observations - as well as the capacity to interact with staff in an effective manner (e.g., utilizing correct terminology and, in this particular case, speaking fluent German). Additionally, more structured efforts could be made to ensure that observers are effective in identifying medical equipment. In a similar way to structuring the knowledge and capacities of observers, such efforts can also be made for staff so that their expectations are more clearly articulated to the research group. In particular, staff expectations regarding what boundaries exist for the observation team seemed to differ between who was observed, and therefore led to incongruent experiences for different observers. An often cited example in observer meetings was in regard to entering patient rooms, or conducting room observations when staff were present. In some cases this was permitted, and in other cases it was not.

Regarding financial accounting data, Figure 3 indicates which categories could be utilized in conjunction with an expanded methodology incorporating a method of converting financial inputs into environmental impact (e.g., via measuring the carbon account of an entity). Though the aspects of this methodological consideration fall outside the scope of this paper, it is nonetheless an important point to consider when determining the impacts of procurement at a hospital.

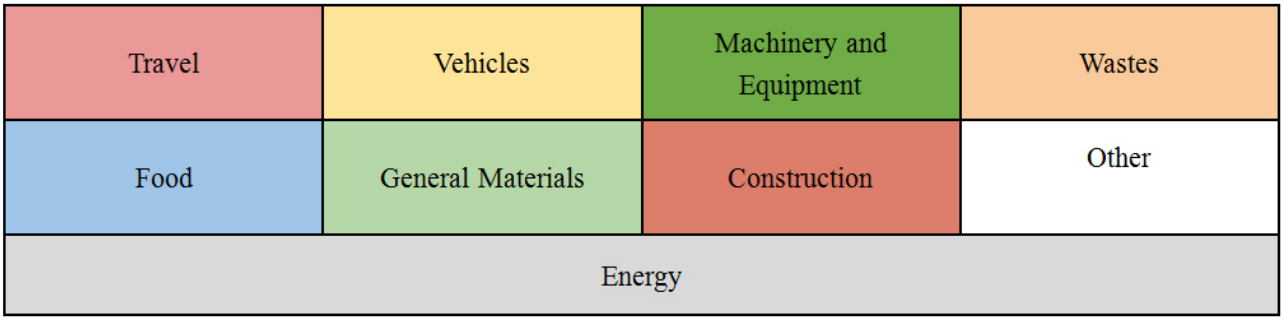

Figure 3. Categories for financial input requirements – own representation

Figure 3 includes financial categories which could be integrated into e.g., a multi-regional input-output (MRIO) analysis, in order to determine the carbon account of an entities procurement. In this particular instance, the product categories in the MRIO model EXIOBASE are used as a reference for financial categorization.[34]

6. Conclusion and Future Research

The conceptual model and observations resulted in the gathering of data that now needs to be used to formulate sustainability strategies for the hospital, in this case the CH in Freiburg. Implementing these sustainability strategies requires continued research and monitoring, through the described methodological approach, to allow comparisons and to provide context for changes in the hospitals sustainability.

Further, employee interviews indicated that food consumption and waste was of high improvement potential for general hospital sustainability.

Additional questions have now arisen, especially given the data on employees focusing on the ecological aspects of sustainability with much less attention paid to social and economic areas. Past research has indicated that involving employees in new sustainability initiatives (whether ecologic, economic or social) is tantamount to success.[17] Reiterating Funk's definition of sustainability as one creating "desirable future states for all stakeholders",[3] it would seem necessary to facilitate sustainability initiatives across all three domains of sustainability: social, ecologic and economic. The question is thus, in which areas of sustainability are employees involved and empowered, and how do these relationships affect the outcomes of these initiatives? The social sphere often includes the involvement of persons with decision-making authority, whom control the operational aspects of an organization - general employees thus see little chance for involvement and influence. Better understanding these dynamics, and thus the sustainability potential of an organization, necessitates further research between actor domains and governance structures.

Given the difficulties in carrying out the applied methodolog-

ical approach, it seems that knowing your facility is indeed a prerequisite, rather than only a result of the sustainability management process. While the conceptual model applied in this study provided an avenue for analyzing the environmentally relevant structures and processes in a hospital, the methodology applied failed to materialize appreciable results given the constraints in carrying out a complex observational study in such a hectic environment as a hospital. Future studies utilizing the framework developed for this analysis would do well to conduct preliminary analyses to determine which analytical pathways will be most possible for acquiring the necessary data.

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CONFLICTS OF INTEREST DISCLOSURE

The authors declare they have no conflicts of interest.

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