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Testing of a Multiple Criteria Assessment Tool for Healthcare Facilities Quality and Sustainability: The Case of German Hospitals

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Abstract: Background: Hospital facilities are an essential part of healthcare systems, making the assessment of their quality and sustainability pivotal. Most existing evaluation tools lack a holistic and validated approach, while predominantly excluding the built environment. The Italian hospital evaluation tool SustHealth v2 addresses the shortcoming of existing applications through its structured and more integrated approach; there is the need for further testing it. Methods: The study aims to test for the first time in an international case study the multicriteria assessment tool previously developed and validated. The tool assesses social, environmental, and organisational qualities in hospitals with an online survey containing 199 closed questions sent to German hospitals. A total of 14 full replies have been collected and the resulting data analysed through descriptive statistics and heat maps identifying patterns in ownership and size. Results: Within the sample, higher scores are reported in Social Quality, while lower in Environmental and Organisational Quality. Respondents performed well in the sustainability dimensions of health promotion, waste management, and patient safety. Improvements can be achieved in energy management, facility management, and technological innovation criteria. Private hospitals slightly outperform both public and non-profit clinics. The findings presented in this study suggest a non-linear relationship between sustainability and hospital size since the highest scores were obtained by either small or large facilities. Conclusion: The study highlighted strengths and limitation of SustHealth v2. Further testing and comparison are encouraged in different context.

Keywords: hospital; sustainability; quality; evaluation tool; healthcare facilities; sustainability of healthcare facilities; social sustainability; environmental sustainability; organisational sustainability

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1. Introduction

1.1. Background

Healthcare systems, as in many other industries, are striving to face sustainability challenges while constantly improving their quality level [1–4]. Hospital facilities are complex infrastructures and an integral part of the system due to their social, environmental, and organizational implications [5]. Frequent conflicts between improving sustainability and providing high-quality service have been highlighted in recent studies [6,7].

Despite recognition of the challenges, research conducted in this area and the current context of rising demand for healthcare services, relatively little progress has been made in supporting the long-term impact of sustainability improvements and tools [8]. The current context of changing priorities and shortage of resources highlights the need to understand how sustainability can be attained in different spheres [9].

For example, there is no specific knowledge transparently available to evaluate in which areas hospitals are sustainable and where there is room to improve. Hence analyzing and assessing the sustainability of hospitals could support the overall healthcare sector's ecological transition [10–13]. Research about hospital sustainability evaluation has increased over recent years [14–18], but there are few cases of hospital departments trying to reduce their ecological footprint in practice [19]. However, the scope of evaluation is still limited and reminiscent of silo mentality. Therefore, more holistic approaches are needed. Additionally, studies have been conducted on sustainability assessment for healthcare facilities in developing countries, and less attention is devoted to high-income countries' hospital quality and sustainability [20–22]. Furthermore, the application of hospital-specific indicators may not be generally applicable to larger samples [23,24]. There is a need to identify practical approaches that measure sustainability and evaluate its outcomes [25,26].

The lack of an evidence-based consensus on how to define sustainability in healthcare is also making its assessment very challenging [27]. Sustainability has, in fact, numerous definitions and meanings to different stakeholders [28], often linked to UN Sustainable Development Goals [29–31] and considered with a Triple Bottom Line of profit, people, and the planet for companies [32–35]. The understanding of hospital sustainability in this study is generally based on Elkington's line of thought that sustainable development requires "*strategies [. . .] to simultaneously benefit the company, its customers, and the environment*" [36]. In that case, healthcare is not solely about people, the planet, and profit, but rather society, the environment, and the organisation. Additionally, according to the Royal College of Physicians, sustainability can be considered one of the six key domains of quality in healthcare, extending the responsibility of providing health services to patients for today and the future [12].

Within these circumstances, SustHealth v2 (Figure 1) is a recently developed multiple criteria tool weighted for sustainability and quality evaluation, built on a set of evidence informed items, validated and weighted in previous studies in Italy and Sweden [37]. It is composed by a survey of 199 closed survey questions that subsequently get converted into binary values. In this way the tool provides a hierarchical scoring model to showcase how hospitals perform in terms of Social, Environmental, and Organisational Quality and sustainability [17,38]. Each of those three macro-areas is further subdivided into five to six criteria to understand the outcome in more detail. Within those, two to four indicators contain the questions whose answers are judged with a specific assessment methodology. It appears to be one of the promising tools for sustainability evaluation in hospitals.

Figure 1. Overview of SustHealth v2 and its criteria (*c*) and respective weightings (*w*) [39].

1.2. Review of Scientific Literature

Consequently, to find out more about sustainability evaluation in hospitals, this literature review summarises other researchers' findings on the topic. As a method in healthcare research, a scoping review is used to identify and analyse knowledge gaps within the broader scope of the subject [40]. This research question that led the process was: "What is known from the existing literature about tools to evaluate quality or sustainability in existing hospitals?".

The search strategy has been limited to the scientific and grey literature part of the electronic databases Scopus and Web of Science, next to external references identified by snowballing and other means (see Figure 2). Appropriate search terms have been defined through a three-level keyword assembly structure linked with the Boolean "AND" term, examining title, abstract, and keywords. The first level defined the general context with "HOSPITAL" as the central entity under investigation. The second level consisted of the terms "QUALITY" or "SUSTAINABILITY" to maintain a broad focus due to the different possible interpretations of the scientific fields that work on the topic. The third keyword level tried to include the actual measurement process and emphasise the subsequent judgement of the previous two terms in hospitals and was defined as "EVALUATION TOOL" or "ASSESSMENT TOOL". The review only included studies published between 2016 and 2021. The start date was chosen since the Paris Agreement went into force that year, a milestone treaty on climate change that subsequently had implications on the healthcare sector in general and hospitals precisely, due to their sizeable environmental footprint. Language material was limited to English, Italian and German languages. Another exclusion criterion adopted was to focus on evaluating hospital operations, therefore not considering the design phases. Finally, documents from the subject area "Medicine" were excluded a priori. Several articles were collected and stored in an Excel spreadsheet, including the respective title, abstract, and keywords.

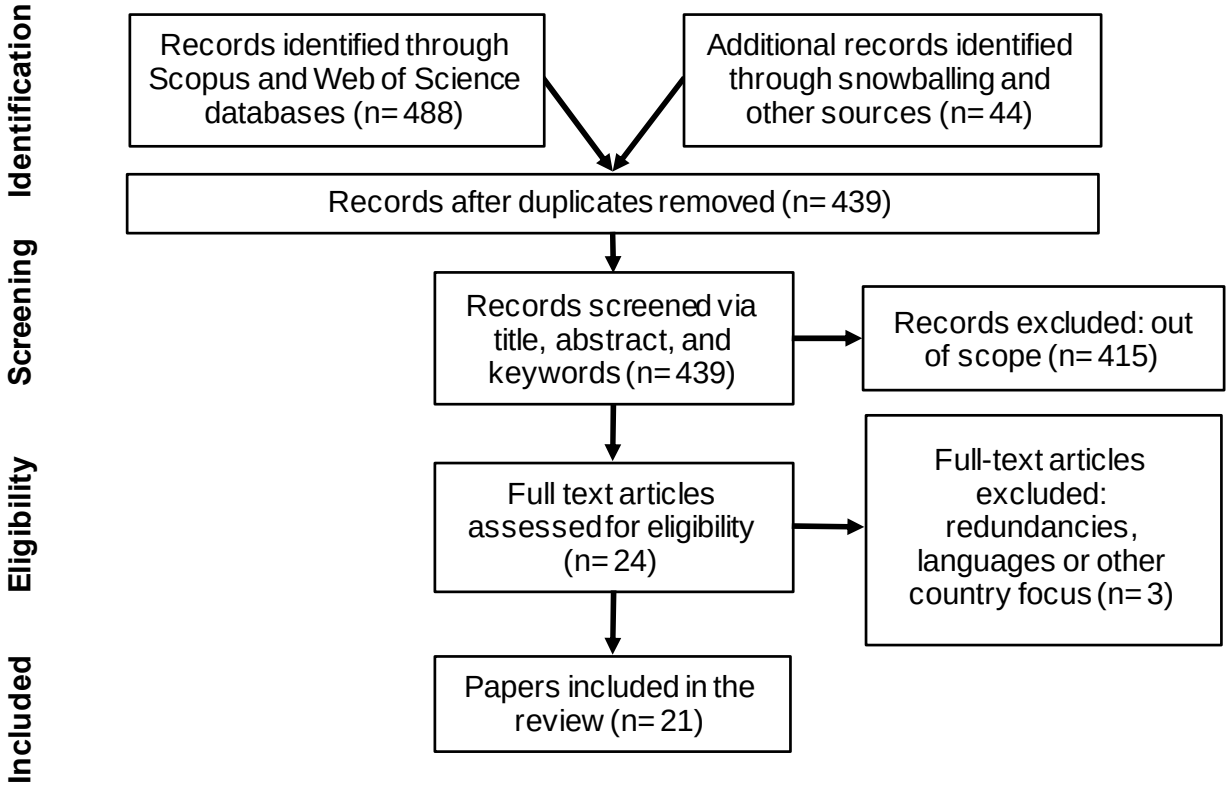

Figure 2. Flow diagram of study selection for scoping review, adapted and based on the Prisma Statement by Moher et al. [41].

The initial search yielded 230 records in Scopus, 258 from Web of Science and 44 records identified through other means. After removing duplicates, it resulted in a total of 439 papers. Furthermore, the obtained records were screened to identify which articles are in and out of scope according to the abstract, title, and keywords. The three exclusion requirements were based on the following topics, resulting in 24 remaining documents:

- Patient: meaning exclusion when the content focuses solely on the patient's well-being, mainly about the disease and subsequent treatment. Parts of the research still had significant overlaps with a medical focus even after omitting the subject area of medicine;
- Countries: Exclusion occurred when results were only relevant for hospitals in low- and middle-income countries;
- Facilities: Omission where the areas under investigation are either not part of the hospital or concerns hospitals still to be built.

Finally, the full text of the remaining papers was read to determine eligibility. Three were excluded where there were redundancies in terms of published content, the language of the work was not written in English or German, or where results only applied to low- and middle-income countries. Finally, 21 papers were included.

To obtain an overview of the literature analysed, several details have been noted in an Excel spreadsheet to enable summary, comparison, and results reporting. The number of researchers in each paper range from one to nine, where the typical number of contributors is between two and four. The originating research countries have been simplified to regions, with almost 60% belonging to Europe and 40% divided almost evenly between South America, Asia, the Middle East, and the United States.

When looking at the theoretical models applied, there appears to be great diversity ranging from Donabedian's quality assurance model [42] to usability theory [43]. The only model applied consistently is evidence-based design in 40% of the cases (inter alia [44–46]). The majority of methodologies are built around systematic literature reviews (inter alia [47,48]), empirical studies (inter alia [49,50]) and the hierarchical analytical process [51,52]. The authors have applied these methodologies 48% of the time quantitatively, 33% mixed, and 19% qualitative methods.

Another aspect of the review concerns the collecting, sourcing, and analysis of the data. The collection took place via survey questionnaires (inter alia [53,54]) or keywords in databases 61% of the time (inter alia [45,55]). The remaining papers had other approaches, for instance, 9% retrospective data collection [56,57] and 9% semi-structured or structured interviews [37,49]. Other collection methods were expert interviews [58], focus groups [59], systematic collections [60], walkthroughs [43], and website data [61]. Data sources mainly consisted of subject matter experts, online databases, the patients themselves, or the staff working at the hospital. The subsequent analysis was conducted in many ways, most notably via descriptive analysis, SPSS, descriptive statistics, and subsequent exploratory factor analysis.

The outcomes led to a new measurement tool in 66% of the sampled articles, or in some cases, an addition, testing, evaluation, or validation of an existing one. In 19% of the cases the outcome was an overview of the research landscape, and almost 10% ended with a new framework. The remaining 5% concluded the research with a specific guideline on hospital sustainability evaluation. Every area analysed can be grouped into a particular hospital topic or a specific focus on one of the hospital's departments, with 67% and 33%, respectively. Major overarching themes included evaluation tools and quality, while divisions under scrutiny were often the care and emergency department. Lastly, the research was mainly intended for hospital management, the patient, or the greater research community. Below are the main findings of the scoping review that had the goal of answering what is known from the existing literature about tools to evaluate quality or sustainability in existing hospitals.

The understanding of the subject matter is broad, relating overall to maintaining or improving high-quality hospital operations meeting the present needs without compromis-

ing future activity. The evaluation tools in the review are manifold in terms of how they were constructed, what aspects they measure, and what conclusions they derive from the evaluation. However, there appears to be a uniting characteristic of creating and validating new tools instead of testing and refining existing standards. Irrespective of the multiple evaluation methods, almost all instruments seem to have a singular focus, concentrating on a single topic relevant to the hospital organisation or analysing solely one department. Reasons could be related to the difficulty of measuring quality and sustainability across areas and departments in healthcare facilities.

As part of this review, only the tool Sustainable High-Quality Healthcare Version 2, or SustHealth v2, was intended to cover the hospital setting in a holistic way, validated in Brambilla et al. [37]. It focuses on analysing operative hospitals' environmental, social, and organisational qualities, making it an evidence-based procedure that could be also useful in practice once further tested and refined.

1.3. Study Objective and Focus

The aim of this study is to test a multiple criteria assessment tool for hospital quality and sustainability in a sample of German hospitals. In particular, it has three research objectives: first, determining the applicability and reliability of the hospital sustainability evaluation tool SustHealth v2 by testing it in Germany; second, looking for commonalities in ownership and the number of patient beds, the latter approximating hospital size; and third, highlighting which areas or criteria deserve more attention for improvement in quality and sustainability within hospital facilities. The study focuses on operating hospitals and facilities that provide inpatient care as their primary goal. Indeed, hospitals under design or construction are not considered.

2. Materials and Methods

2.1. Methodological Approach

This study is based on Design Science (DS) and Design Science Research Methods (DSRM) traditionally used in engineering and information systems research [62,63], but also recently adopted in management and multidisciplinary studies [64]. DS has been recommended as a new paradigm for conducting research [65–68], simultaneously meeting scientific and practical relevance [69]. Thanks to the gap identification and the development of an artefact (assessment tool), it is possible to mitigate the relevance problem through a solution-oriented approach [70]; in fact, DSRM supports the investigation of the problem and finds employable solutions eventually applicable by both academics and professionals in the field. This research builds upon previous work on the SustHealth v1 assessment tool for operating hospitals [14] and, in particular, the updated version SustHealth v2 [39]. Based on DSRM, the study is targeting the evaluation step and has a specific focus on testing an artefact (in this case SustHealth v2) [71]. Starting from Gregor and Hevner's definitions [72], the specific contribution of this study is that of an improvement, which means that this kind of input helps to address a known problem and offers a new solution or substantial enhancement to an existing one. The known problem is the difficulty of measuring and evaluating quality and sustainability within healthcare facilities in high-income countries like Germany. The enhancement comprises the speed, holism and strong validation of the newly built evaluation tool compared to existing alternatives.

2.2. Data Collection

Data have been collected with SustHealth v2 tool, a multiple criteria assessment framework composed by an operative checklist for hospital assessments previously developed, weighted and validated [14,39]. The tool is divided into three different macro-areas of Social, Environmental, and Organisational Quality. The hierarchic framework is structured into a subsequent level of five to six criteria and two to four indicators each, where every indicator has a specific assessment methodology, as exemplified in Figure 3. These, in

turn, are measured via two to nine different variables. The questions in the variables are primarily binary or ask for the provision of absolute values.

The results obtained in each variable have been aggregated at the indicator, criterion and macro-area levels based on the structure of SustHealth v2, as shown in Figure 3.

The macro-area 1. Social Quality includes all items related to the improvement of human activities carried out within the hospital setting and refers to the necessity that the hospital must boost wellness, wellbeing, satisfaction, safety, and inclusion. It is described through the six criteria: 1.1 Hospital Accessibility, 1.2 Security Enhancement, 1.3 Customisation and Empowerment, 1.4 Social Inclusion, 1.5 Health Promotion and Education, and 1.6 Visual Environment.

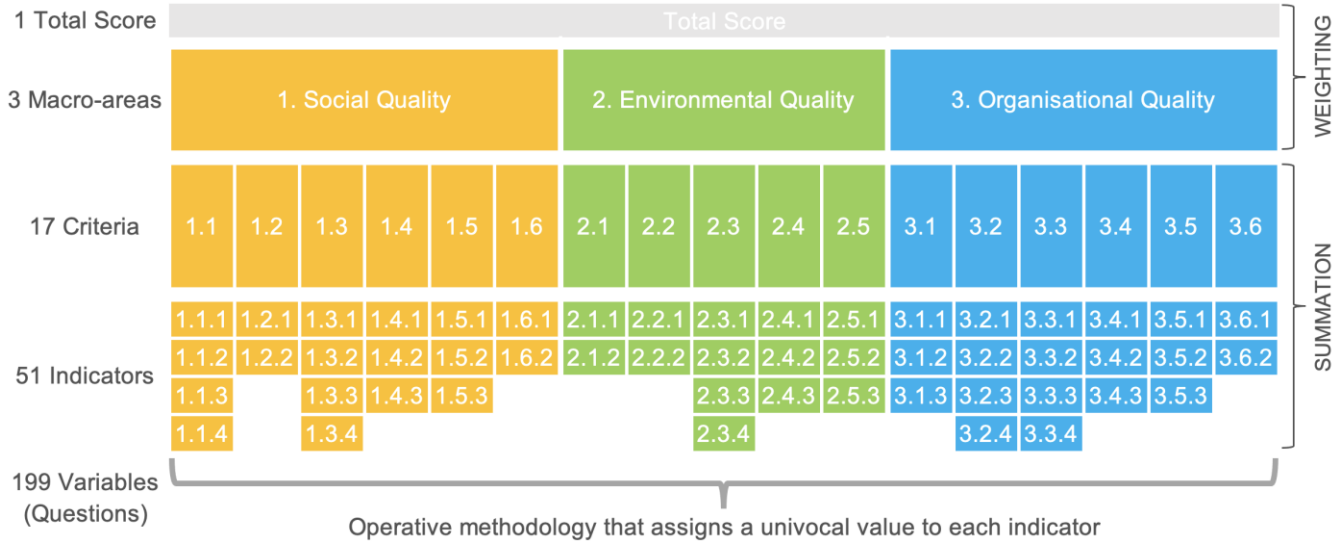

Figure 3. Assessment tool framework.

2. Environmental Quality, as the second macro-area, includes all the items related to the rationalisation of waste, the development of renewable resourcing, and sustainable energy and space management. This macro-area contains five criteria: 2.1 Policies and Education, 2.2 Waste Management, 2.3 Energy Management, 2.4 Perceptive Wellbeing, and 2.5 Wayfinding and Ergonomics.

The third macro-area, 3. Organisational Quality, monitors that the organisation provides or controls sustainably, efficient policies and activities for the proper management of the overall facility, including innovation, monitoring, certification, and risk management. Defining criteria are: 3.1 Patient Safety, 3.2 Survey and Monitoring, 3.3 Future-Proofing, 3.4 Logistics and Efficiency, 3.5 Technological Innovation, and 3.6 Facility Management. Figure 4 shows a categorisation of these components coloured according to the respective macro-area, while a detailed description of the tool development and validation is reported in previous studies [37,39,42].

To operationalize the assessment on the German hospital sample, the 199 variables have been translated into an online survey in German. The survey was created on the survey platform SurveyMonkey and diffused via email [73]. The final questionnaire contains 199 questions in total with five different response options, of which 86.9% can be answered by "yes" or "no" and 11.6% by providing a value between 0–100%. The remaining 1.5% need a specific numerical value as an answer. In addition to the specific questions, the survey provides context on indicator level about the description of the topic, the intent, the scientific sources, and the impact on individual health, environment, and organization.

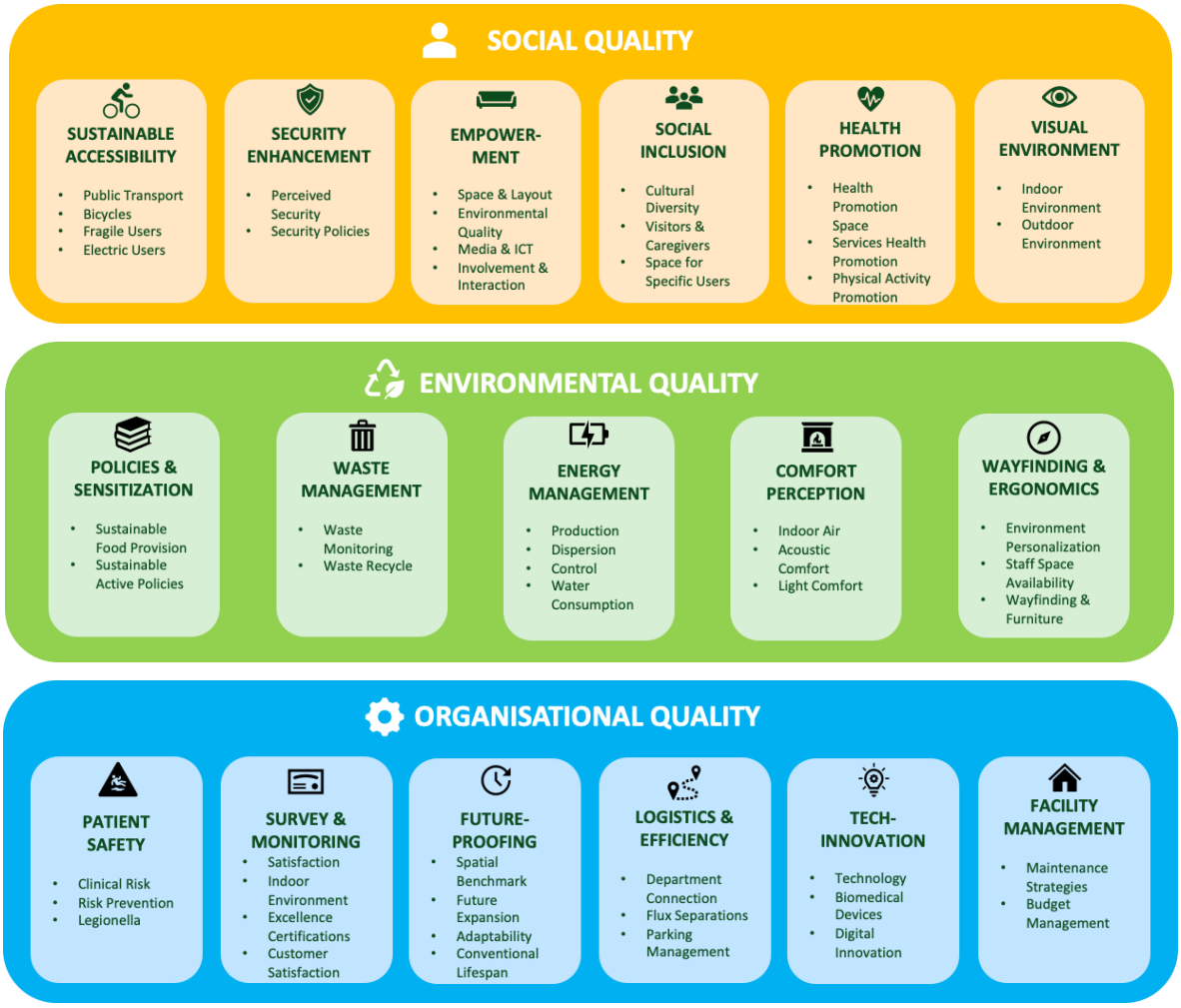

Figure 4. SustHealth v2 measurement criteria.

2.3. Sample Selection

Germany appears to be a suitable country for further inquiry. Among member states of the European Union (EU), it has the highest number of hospital beds relative to population size [74]. This fact makes insights about that geography impactful, as improvements are directly applicable to many patient beds and in turn many hospitals. The sample selection was based on all hospitals in Germany (n = 1914) and is visualized in Figure 5. Following this step, the size was reduced by only including hospitals part of the *German Hospital Directory* at the end of 2019, which serves as the latest official German registry for hospitals (n = 91). Clinics without patient beds (n = 52) such as outpatient facilities or primary care centres have been excluded. The 1771 remaining hospitals were contacted via email stored in the *German Hospital Directory*, contact forms found on the respective websites, and via initiatives concerned with sustainability and quality in the healthcare sector, for instance, KLIK [75]. This latter ensures a higher relative response rate although makes sample selection more likely to be biased towards sustainability and quality. Either way, an attempt was made to get in touch with the head of quality or the sustainability/climate manager in each interested hospital. They acted as the central contact people for answering the survey and involved other organizational areas, if necessary, like the technical office, investment planning, management and control, risk management, and clinical engineering. From the received responses, 30 hospitals were interested in the project, of which 17 participated in the questionnaire. Finally, 14 responses were fully completed and could be used for further analysis.

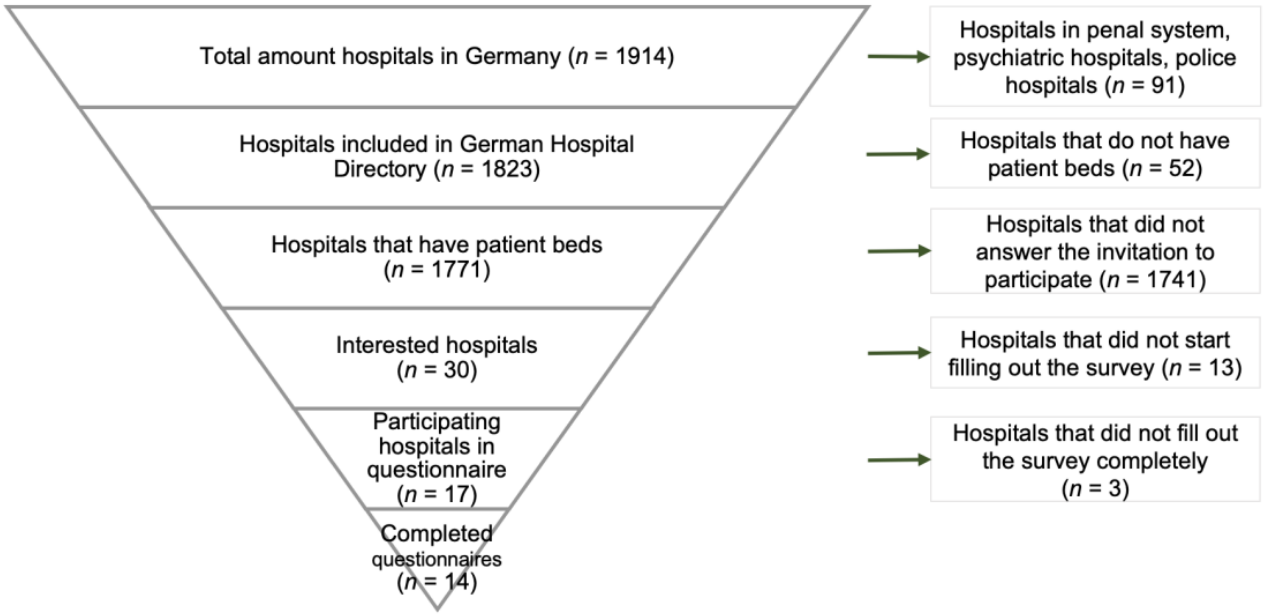

Figure 5. Sample selection of participating hospitals for survey.

The survey was conducted online between 25 October and 6 December 2021, and the typical time spent for completion was around 3 h and 10 min. To compensate the participating hospitals for their input and time, every hospital received a dedicated SustHealth HospitalReport, containing individual scorings and a benchmarking between all hospitals. The sample of participating hospitals in this case study can be described according to several characteristics. Due to the small sample size, inferential statistics are not applied. All clinics are in 9 out of the 16 German regions (*Länder*). However, Figure 6 shows that the sample is concentrated in the north and south of Germany without many respondents in the country's centre.

Hospital	Patient Beds	Hospital Type	Ownership	State
Hospital 1	680	Plan Hospital	Public	Bavaria
Hospital 2	238	Plan Hospital	Non_Profit	Berlin
Hospital 3	175	Plan Hospital	Non_Profit	Baden-Württemberg
Hospital 4	188	Plan Hospital	Private	Bavaria
Hospital 5	18	Plan Hospital	Private	Lower Saxony
Hospital 6	303	Plan Hospital	Public	Baden-Württemberg
Hospital 7	456	Plan Hospital	Non_Profit	Bremen
Hospital 8	431	Plan Hospital	Public	North Rhine-Westfalia
Hospital 9	321	Plan Hospital	Public	North Rhine-Westfalia
Hospital 10	271	Plan Hospital	Non_Profit	Berlin
Hospital 11	216	Plan Hospital	Private	Bavaria
Hospital 12	448	Plan Hospital	Public	Brandenburg
Hospital 13	671	Plan Hospital	Public	Saxony-Anhalt
Hospital 14	1437	University Hospital	Public	Hamburg

Figure 6. Locations and details of hospitals participating in the case study.

2.4. Data Analysis

The survey data were exported to Microsoft Excel after anonymizing the individual hospitals. A nomenclature is reported below in Table 1 as reference for the further description of this section.

Table 1. Nomenclature used in this study.

Acronym	Full Name
m	Macro area
c	Criterion
i	Indicator
v	Variable of each question, the desired answer according to methodology
r	Reply to each question in the questionnaire
T	Total score
S_m	Macro-area score
W_m	Macro-area weight
u_c	Criterion score
U_c	Maximum possible criterion score
$\hat{u}_c$	Standardised criterion score
w_c	Criterion weight
v_i	Indicator score
V_i	Maximum possible indicator score
$\hat{v}_i$	Standardised indicator score
v	Variable of each question, the desired answer according to methodology

Every participant's answer to each question was converted into quantitative values in the form of a binary system based on a univocal choice. If the reply (r) completely satisfies variable (v) or, in other words, if r reached or exceeded the cut-off limit imposed by v a value of 1 was assigned. Otherwise, if r could not completely fulfil v or did not reach the limit imposed, a value of 0 was assigned. Even though adopting a binary system can be seen as rigid, it simplifies usability and efficiency in the evaluation without extensive loss of information.

The first level of outcomes is that of indicators (i). Dividing the indicator value (v_i) by the maximum possible score (V_i) leads to the standardised indicator score ($\hat{v}_i$) (see Equation (1)).

$$\hat{v}_i = \frac{v_i}{V_i} \tag{1}$$

The second level of the hierarchic framework concerns the scoring of the individual criterion (c). Summation of all indicators belonging to c (v_i) leads to the criterion score (u_c) (see Equation (2)). Then, dividing u_c by the maximum possible score (U_c), it is possible to define the standardised criteria score ($\hat{u}_c$) (see Equation (3)). This result for each criterion is a rational number between 0 and 1, where 0 indicates that no item has been fulfilled and 1 shows that all items are satisfied.

$$u_c = \sum_{\substack{\text{indicators } n \\ \text{in criterion } c}} v_i \tag{2}$$

$$\hat{u}_c = \frac{u_c}{U_c} \tag{3}$$

The third and highest level of SustHealth v2 deals with the macro-areas (m) and the total score (T). The macro-area score (S_m) gets calculated by multiplying each standardised criteria score ($\hat{u}_c$) with each weight pre-assigned to each criterion (w_c) and summing together all c belonging to each m (see Equation (4)). Lastly, the summation of the product of all S_m with the corresponding macro-area weight (W_m) generates T, a number between 0 and 1, expressing the final aggregated performance of the individual hospital (see Equation (5)).

Further details about the process of weightings for criterion and macro-area level were described in previous studies [37].

$$S_m = \sum_{\substack{\text{criteria } c \text{ in} \\ \text{macro area } m}} \hat{u}_c \times w_c \quad (4)$$

$$T = \begin{array}{l} S_{\text{Environmental}} \times W_{\text{Environmental}} \\ +S_{\text{Social}} \times W_{\text{Social}} \\ +S_{\text{Organisational}} \times W_{\text{Organisational}} \end{array} \quad (5)$$

The weights used are derived from the previous studies conducted and resulting from a Multiple Criteria Decision Aiding (MCDA) weighting process [76,77]. Semi-structured interviews and the application of the Simon Roy Figueras (SRF) procedure for the elicitation of weights criteria through the Deck of Card Methods allowed us to involve international experts and decision makers from the healthcare sector supporting the weight definition [37,78]. The summary of weights used in this study is reported in Table 2.

Table 2. Macro area and criteria weights [37].

Macro-Areas	*W*	Criteria	*w*
1. Social qualities (S)	22%	1.1 Sustainable Accessibility (SA)	16%
		1.2 Security Enhancement (SE)	19%
		1.3 Involvement and Empowerment (IE)	21%
		1.4 Social Inclusion (SI)	18%
		1.5 Health Promotion (HP)	11%
		1.6 Visual environment (VE)	15%
2. Environmental qualities €	29%	2.1 Policies and Sensitization (PS)	18%
		2.2 Waste Management (WM)	8%
		2.3 Energy Management (EM)	20%
		2.4 Comfort Perception (CP)	23%
		2.5 Wayfinding and Ergonomics (WE)	31%
3.Organizational qualities (O)	49%	3.1 Patient Safety (PS)	18%
		3.2 Survey and Monitoring (SM)	17%
		3.3 Future Proofing (FP)	23%
		3.4 Logistics and Efficiency (LE)	13%
		3.5 Technological Innovation (TI)	15%
		3.6 Facility Management (FM)	14%

Data have been analysed with descriptive statistics to understand different scoring in terms of macro area and criteria. Furthermore, heat maps have been developed to identify patterns in ownership (public, private, not profit) and size (considering as a proxy difference in patient beds number). Finally, feedback has been collected from the respondents to verify strengths and weaknesses in the applicability of SustHealth v2.

3. Results

3.1. Descriptive Statistics

The sample of respondents (n = 14) is composed of 13 regular Plan Hospitals and 1 University Hospital. Considering ownership, 50% of the sample are publicly held, 29% not-for-profit organisations and 21% private companies. The number of patient beds per hospital varies over an extensive range from 18 to 1437 beds, with a median of 312. The analysis starts by converting closed questions into quantitative values. The scatterplot in Figure 7 shows the standard deviation of the binary values in each question, thereby measuring the dispersion of the dataset relative to its mean. The different colour coding and symbols indicate affiliation to each macro-area. The x-axis displays the position of each question in the survey, with one being the first and 199 the last, and the y-axis yields the corresponding dispersion of the values. Only 9% have a standard deviation of 0.0 meaning answers were the same, while 26% lie within 0.2 and 0.4, and 65% of the questions are

higher than 0.4. It appears that high standard deviations are spread evenly around the survey, though low standard deviations have a higher prevalence between questions 17 to 70 and 108 to 146. The subsequent calculations previously outlined were completed for all 14 hospitals, and the results are consolidated and presented below. Numbers have been rounded off to the third decimal place for calculation and the second decimal place for visualisation.

Figure 7. Standard deviation of the answered questions in sample, standard deviation of 0 across all questions circled in red.

3.2. Functionality of SustHealth v2

To get a better idea about the evaluation, the tool's functionality, and how it is used, the analysis of *Hospital 2* serves as an exemplary case on macro and criteria level. The three macro-areas below are highlighted each in orange, green, and blue. The results of the criteria and macro-area scores are colour coded to facilitate a more straightforward overview about which areas to prioritise. Coding is based on a 3-Colour Scale, where red is assigned to the lowest possible value 0.0, yellow to 0.5, and green to the maximum score of 1.0.

A first overview for the hospital is given in Figure 8 on macro area level, showing the total score (T) and the performance in Social Quality (S), Environmental Quality (E), and Organisational Quality (Q). This level 1 overview of *Hospital 2* indicates a total score of 0.49. The colouring of S_m indicates that the low performance is attributable primarily to Environmental and to some extent Organisational Quality. Level 2 includes the criteria belonging to each previously shown macro-area. The criteria of 1. Social Quality are displayed in the upper third of Figure 8, showing an excellent overall score of 0.73 with average or above-average points in all criteria, most strikingly a score of 1.00 in 1.3 Involvement and Empowerment. On the other hand, 2. Environmental Quality scores significantly lower than the previous area with 0.32 in the centre of Figure 9. All indicators could be further analysed; here, a focus could be on 2.3 Energy Management with 0.12, 2.1 Policies and Sensitisation with 0.22, and 2.4 Comfort Perception with 0.29. The remaining macro-area 3. Organisational Quality scores below average with 0.49. From what is observable in the lower third of Figure 8, several indicators deserve a more thorough analysis. Notably 3.5 Technological Innovation with 0.27 and 3.4 Logistics and Efficiency with 0.36.

HOSPITAL	Hospital 2	
MACRO AREA	S_m	W_m
1. SOCIAL QUALITY (S)	0.73	21.86%
2. ENVIRONMENTAL QUALITY (E)	0.32	28.98%
3. ORGANISATIONAL QUALITY (O)	0.49	49.17%
TOTAL (T)	**0.49**	

Figure 8. SustHealth v2 exemplary overview of macro-areas from *Hospital 2*.

HOSPITAL	Hospital 2			
MACRO AREA			S_m	W_m
1. SOCIAL QUALITY (S)			0.73	21.86%
Criteria (c)	u_c	U_c	$\hat{u}_c$	w_c
1.1 Sustainable Accessibility (SA)	8	13	0.62	16.18%
1.2 Security Enhacement (SE)	9	12	0.75	19.11%
1.3 Involvement and Empowerment (IE)	11	11	1.00	21.19%
1.4 Social Inclusion (SI)	7	12	0.58	18.23%
1.5 Health Promotion (HP)	6	11	0.55	10.75%
1.6 Visual Environment (VE)	6	8	0.75	14.54%
2. ENVIRONMENTAL QUALITY (E)			0.32	28.98%
Criteria (c)	u_c	U_c	$\hat{u}_c$	w_c
2.1 Policies and Sensitization (PS)	2	9	0.22	18.33%
2.2 Waste Management (WM)	4	8	0.50	7.48%
2.3 Energy Management (EM)	2	17	0.12	19.82%
2.4 Comfort Perception (CP)	2	7	0.29	23.22%
2.5 Wayfinding and Ergonomics (WE)	7	14	0.50	31.16%
3. ORGANISATIONAL QUALITY (O)			0.49	49.17%
Criteria (c)	u_c	U_c	$\hat{u}_c$	w_c
3.1 Patient Safety (PS)	7	10	0.70	17.81%
3.2 Survey and Monitoring (SM)	9	16	0.56	16.54%
3.3 Future Proofing (FP)	7	14	0.50	23.26%
3.4 Logistics and Efficiency (LE)	4	11	0.36	12.90%
3.5 Technological Innovation (TI)	4	15	0.27	15.03%
3.6 Facility Management (FM)	5	11	0.45	14.46%
TOTAL (T)			**0.49**	

Figure 9. SustHealth v2 macro-areas with criteria from *Hospital 2*.

3.3. Evaluation at Macro Area and Criteria Level

Findings of the evaluation are reported at Macro area and Criteria level. Social Quality macro area scored a mean of 0.65 and a median of 0.68. Here, and in the other macro-areas, analysing the mode is not insightful as the resulting variables can take on any number of decimal places; hence, it is not considered in the analysis. The range is 0.39 and the average variability, as measured by the standard deviation, is 0.11. Environmental Quality macro area scores a slightly lower mean and median with 0.51 and 0.49, respectively. The range is 0.35, and the standard deviation is 0.11. Organisational Quality scores similarly to Environmental Quality, with a mean of 0.50 and a median of 0.49. Its range was the highest with 0.46, and the standard deviation is 0.12. The total score has a mean of 0.54 and a median of 0.51. The range is 0.39, and the standard deviation is the lowest at 0.10 as reported in Table 3.

Table 3. Descriptive statistics of the sample at macro area level.

	Social Quality	**Environmental Quality**	**Organisational Quality**	**Total (T)**
Variable	ms	ms	ms	T
Mean	0.65	0.51	0.50	0.54
Median	0.68	0.49	0.49	0.51
Range	0.39	0.35	0.46	0.39
Standard deviation	0.11	0.11	0.12	0.10

In the Environmental and Organisational Quality areas, the sample reports a lower average score, which is higher in Social Quality. The differences between the mean and median are remarkably close. Social and Environmental Quality vary less across the sample, whereas Organisational Quality has the highest difference between maximum and minimum values. Variability, as measured by standard deviation, is similar across all macro-areas.

A further perspective on the sample is obtained by means of visualising hospital scores according to individual criteria and macro-areas. This was obtained using clustered column charts for every macro area/criterion and plotting all participating hospitals on the *x*-axis. Here, the *y*-axis displays the possible scoring from 0 to 1. A dotted line shows the Relative Score Rate (or RSR), which indicates how high an average hospital from the sample fulfils the optimal result. In the macro-areas level, all outcomes from the survey show an RSR of 50–65%, whereas Social Quality scores the highest and Organisational Quality the lowest; therefore, detailed findings are reported at criteria level.

The first macro-area, Social Quality, involves the criteria of 1.1 Sustainable Accessibility, 1.2 Security Enhancement, 1.3 Involvement and Empowerment, 1.4 Social Inclusion, 1.5 Health Promotion, and 1.6 Visual Environment. Here, the highest RSR is in Health Promotion with 72% and the lowest in Sustainable Accessibility with 62%. As shown in the lower half of Figure 10 below, the continuously high and homogenous rates of Health Promotion stand in contrast to the scores in Sustainable Accessibility in the upper half, where hospitals' scoring varies more widely but is still relatively high.

Environmental Quality consists of 2.1 Policies and Sensitisation, 2.2 Waste Management, 2.3 Energy Management, 2.4 Comfort Perception, and 2.5 Wayfinding and Ergonomics. This area has more significant data variation than Social Quality, where hospitals have the highest RSR in the criterion Waste Management. Half of them have a score surpassing 0.88, leading to an average RSR of 71%. On the other end of the spectrum is Energy Management, where hospitals perform low with an average RSR of 32%. Both criteria are visualised in Figure 11.

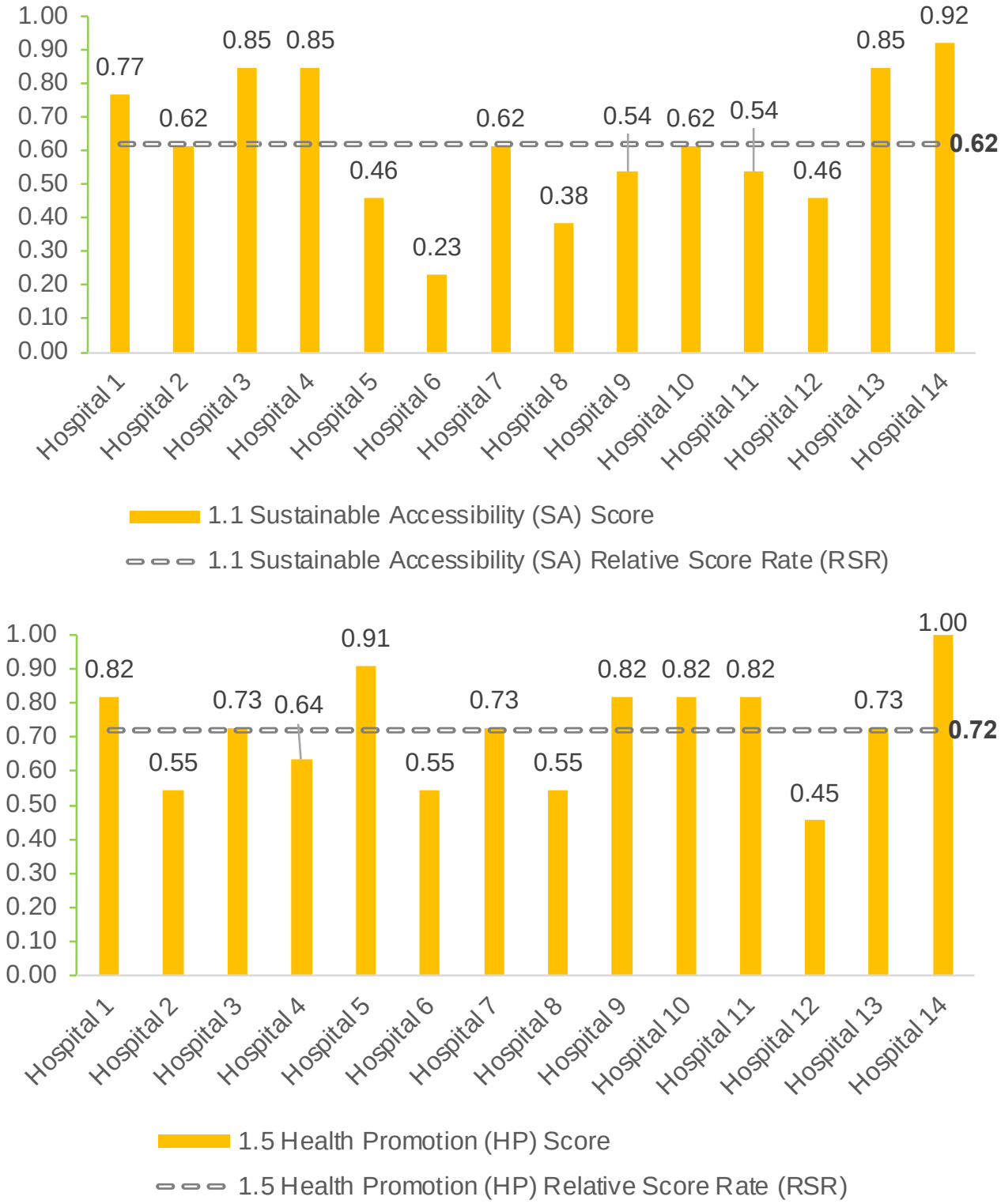

Figure 10. Hospital scoring and relative score rate in criteria Sustainable Accessibility and Health Promotion.

The criteria level of Organisational Quality provides details on 3.1 Patient Safety, 3.2 Survey and Monitoring, 3.3 Future Proofing, 3.4 Logistics and Efficiency, 3.5 Technological Innovation, and lastly, 3.6 Facility Management. Within these criteria, Patient Safety has the highest RSR with 69% and is the only criterion with a relatively strong scoring according to the methodology of SustHealth. With problematic spheres like Facility Management (RSR of 39%), the hospitals score the lowest in this macro-area (see Figure 12).

Figure 11. Hospital scoring and relative score rate in criteria Waste Management and Energy Management.

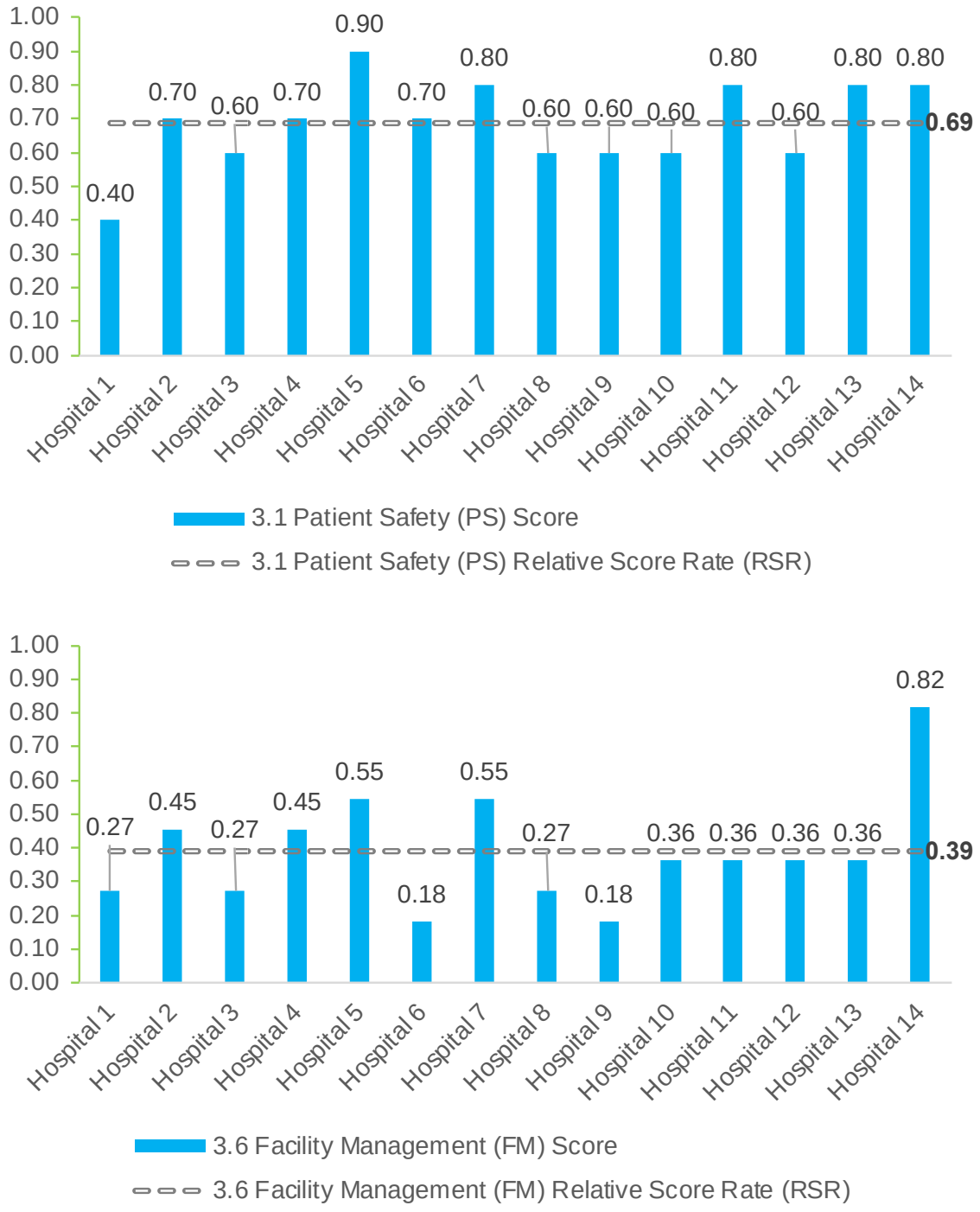

Figure 12. Hospital scoring and relative score rate in criteria Patient Safety and Facility Management.

3.4. Evaluation Based on Hospital Size and Ownership

Following the understanding of high and low scoring in specific criteria and macro-areas, heatmaps have been developed to visualize criteria and macro-level in relationship to specific hospital characteristics such as ownership type (private, non-profit, or public owners) and the number of patient beds, which is a representative metric for hospital size. Heatmaps were generated by averaging the hospital scores according to the respective level and characteristics. The resulting scores are shown in a graded colour scale from red (0.0), over yellow (0.5), to green (1.0). All heatmaps confirm the analytical results and shed new light on new potential patterns connected to hospital characteristics.

Several points stand out when plotting ownership type in connection with criteria in Figure 13. The upper third of the matrix concerns Social Quality criteria, and the scoring is high enough that almost all criteria are green with few exceptions across all types of ownership. Only Social Inclusion stands out where non-profit hospitals perform lower. In the centre of the matrix, the criteria for Environmental Quality show a more varied colour spectrum. Public hospitals in the sample appear slightly better in Waste Management. Private clinics score higher in Comfort Perception, and non-profits have the lowest score in this criterion. However, all three ownership types score low on Energy Management. The lowest third display criteria of Organisational Quality. Overall, privately owned hospitals seem to have an edge in Patient Safety and Future Proofing, though they score comparatively lower in Logistics and Efficiency and Technological Innovation. Public hospitals score lowest in Facility Management, even though it is relevant that all three ownership types have criticalities in Technological Innovation and Facility Management criteria.

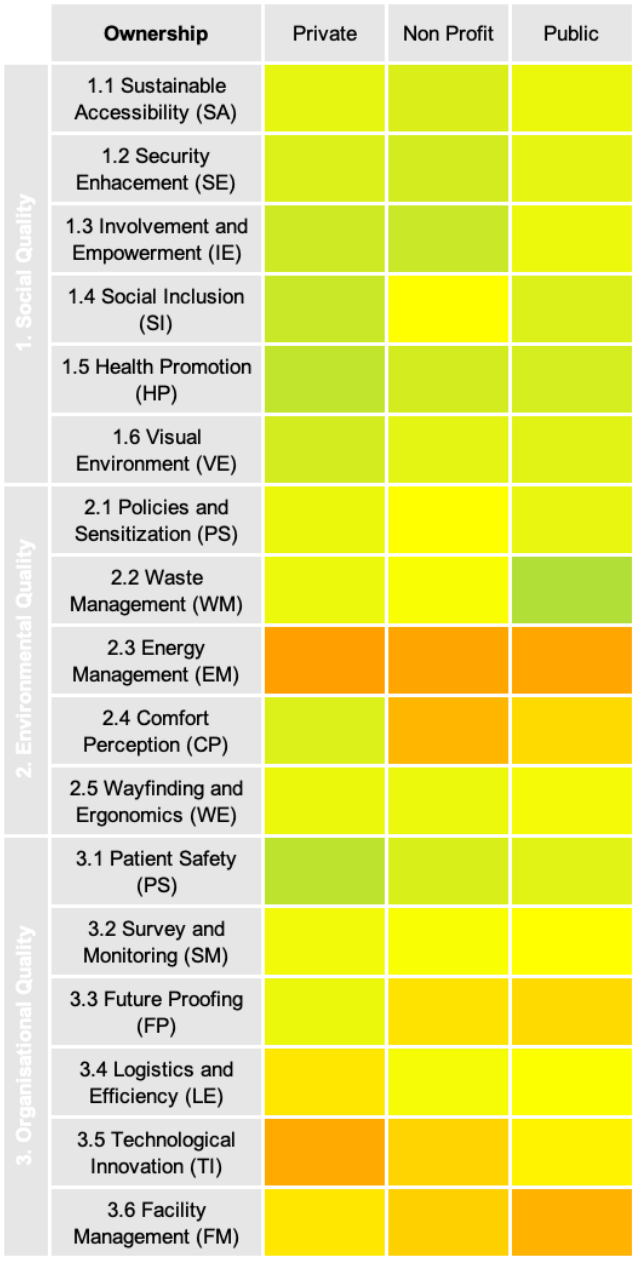

Figure 13. Heatmap on criteria level according to ownership type. The resulting scores are shown in a graded colour scale from red (0.0), over yellow (0.5), to green (1.0).

The heatmap on criteria level differentiated according to patient beds is reported in Figure 14. Criteria in Social Quality (upper third) score mostly high, especially the bracket of 1–150 beds, despite a lower score in Sustainable Accessibility. Bigger hospitals (151–600) perform slightly lower across all categories, especially in Sustainable Accessibility and Involvement and Empowerment. The scoring improves again with 601 or more beds, resulting in slightly green to green areas. In Environmental Quality, smaller and bigger hospitals report better performance, even though Energy Management and Comfort Perception are criteria for low scores, irrespective of the hospital's size. Organizational Quality displays overall higher scores in Patient Safety but presents opportunities for improvement in Survey and Monitoring and Future Proofing for medium-sized hospitals. Logistics and Efficiency appear as a low-scoring area for small hospitals, and Technological Innovation and Facility Management are areas that have a low score for small and medium-sized realities.

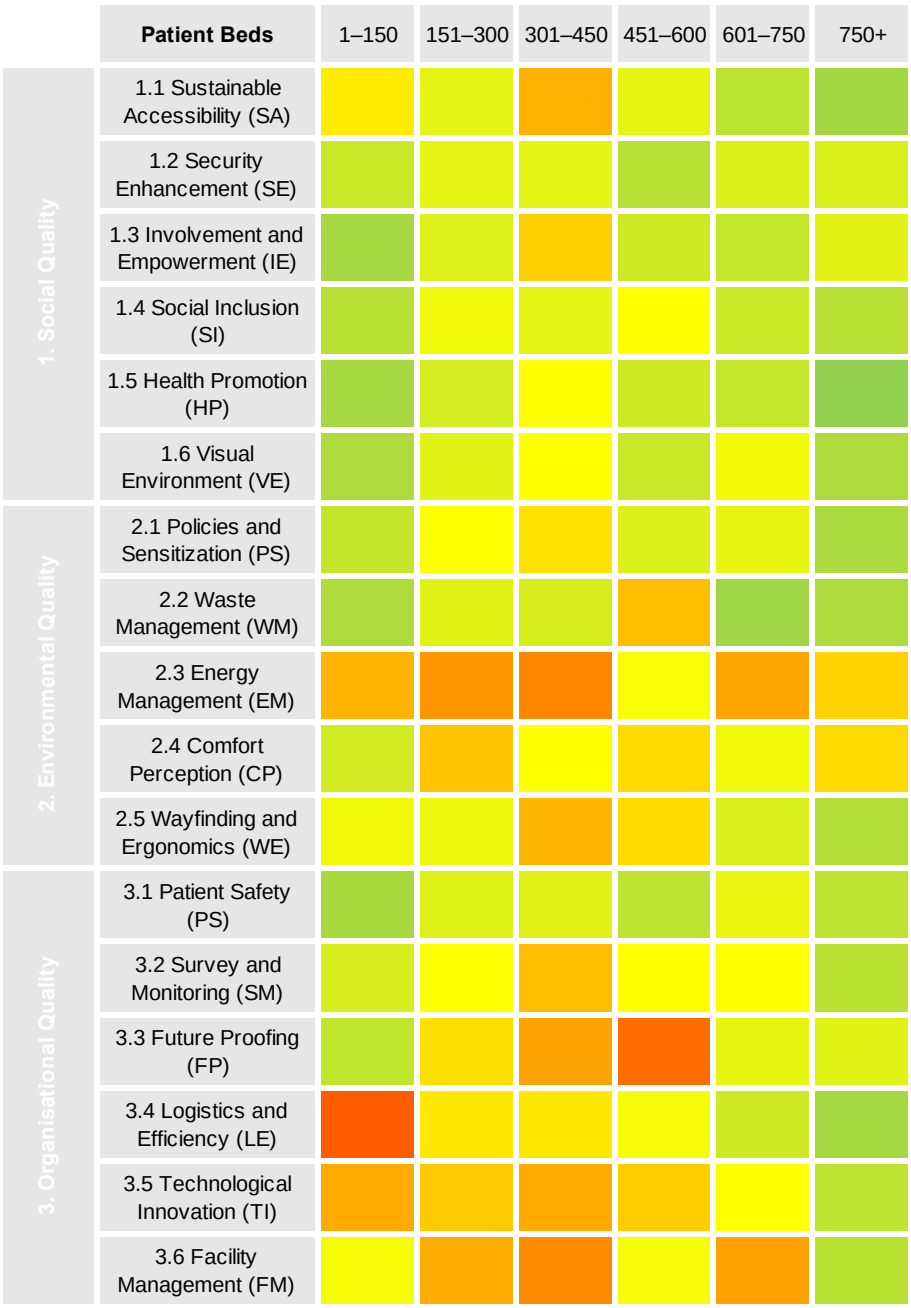

Figure 14. Heatmap on criteria level according to patient beds. The resulting scores are shown in a graded colour scale from red (0.0), over yellow (0.5), to green (1.0).

4. Discussion

4.1. Commonalities Based on Ownership and Patient Beds

The ownership pattern displays an interesting picture of the current state of sustainability, where performance in some areas can be attributed to one kind of ownership, like Comfort Perception. In contrast, there are several topics all hospitals struggle to manage irrespective of what kind of entity owns them, for example, Energy Management and Technological Innovation. Sustainability performance in all hospitals is high in Social Quality, but all kinds of clinics must improve in Environmental and Organisational Quality, especially non-profits and public ones. Private hospitals seem to be the slightly leading ownership type across most areas. Still, this indicates that the level of sustainability a hospital has can only be partly explained by ownership, as issues are rather of horizontal than vertical nature; there might also be a connection to the highly regulated environment of the healthcare industry that gives only limited leeway. Nevertheless, the results are compatible with research suggesting that private hospitals and smaller hospitals have a competitive edge in sustainability [79,80].

Regarding size, and independently of the area under investigation, hospitals score higher in sustainability when very small or very big. The closer a hospital moves towards the middle-sized beds bracket, the worse it performs in the sample. A reason for that could be that small hospitals have a manageable size for taking care of sustainable operations, and huge ones have the necessary professionalism. Another aspect concerns economies of scale: larger hospitals might reduce costs per output more effectively than smaller institutions, enabling cost savings and targeted capital investment to enhance sustainability practices [81]. When a hospital is in the middle, it might have the worst of both worlds; a size big enough to lose the overview but too small to run professionally and cost-effectively in terms of sustainability. Further studies on these aspects should be conducted on a larger sample to better understand the relationship between hospital size and sustainability.

4.2. Strenghs and Weaknessess within the Sample

The second research question deals with the strengths and weaknesses of German hospitals that participated in the survey regarding sustainability and, consequently, the areas deserving the most significant attention, starting with 1. Social Quality.

Criteria here score the highest in all macro-areas. However, the better criteria include 1.5 Health Promotion, 1.3 Involvement and Empowerment, 1.2 Security Enhancement, and 1.6 Visual Environment. The first criterion's performance can be explained by high scores in the indicator's health promotion space and services for health promotion. Physical activity promotion is where many hospitals score the highest or relatively low points. Involvement and Empowerment is another healthy criterion due to the excellent performance of the hospitals in space and layout customisation, control of environmental quality, media, information and communication technology, and places for involvement and interaction. Security Enhancement is another strength of hospitals, characterised by good performance in perceived security and security policies. Visual Environment is also scoring highly in hospitals in the indoor and outdoor visual environment.

On the other hand, low scores can be found in 1.1 Sustainable Accessibility and 1.4 Social Inclusion. The former has high scores in the accessibility to public transport. However, hospitals are on par with, or below average, when it comes to accessibility for bicycles and vulnerable users such as people in a wheelchair or pregnant women. Very low scoring is visible in the accessibility for drivers of electric cars, as dedicated parking spaces and charging stations are missing so far in the infrastructure of hospitals. Social Inclusion shows sufficient space for visitors, caregivers, and specific users like children, blind persons, and people with dietary requirements. Nevertheless, there is some catching up to do in cultural diversity inclusion in the form of a more extensive offering when it comes to translation into more languages than German, cultural mediation, and places for worship and general religious activity.

Still, immediate attention should be directed to increasing the accessibility of clinics for bicycles, fragile users, and drivers of electric cars next to the inclusion of cultural diversity. These shortcomings underline the macroeconomic shift from the combustion engine as the traditional form of transport to other propulsion technologies and modes of transport [82,83]. The other trend is individualisation and multi-culturalism, driven by increased immigration, personal freedom of choice and individual self-determination [84–86]. Hospitals must adapt to the changing nature of their patients to remain in operation in the long run, as patients increasingly demand more from their healthcare services and expect to be treated more like customers [87].

Highly ranked criteria are in 2. Environmental Quality include 2.2 Waste Management, 2.1 Policies and Sensitisation, and 2.5 Wayfinding and Ergonomics. Waste Management shows that hospitals appear to have a solid understanding of waste monitoring and recycling. Within Policies and Sensitisation, clinics seem to have adequate policies for proactive sustainability, but significant latitude remains in how sustainable food is procured. Wayfinding and Ergonomics shed light on the fact that hospitals have concepts in place concerning wayfinding and perform averagely in the availability of staff space and the personalisation of the staff's environment.

Hospitals' significant problems in terms of their Environmental Quality lie in criteria 2.3 Energy Management and 2.4 Comfort Perception. Key areas of concern are lacking production and use of renewable energy and the dispersion, efficiency, management, and control of energy next to water consumption and usage. Hospitals, in effect, do not obtain enough energy from renewable sources, and the built environment is not constructed according to the latest standards to make energy use more efficient and control it structurally [88,89]. Similarly, water consumption and usage are not monitored sufficiently to reduce water wastage automatically, or by rainwater recovery. Although this problem is not highly relevant in Germany, it remains an area where hospitals score low and can improve. Problems of the hospitals' Comfort Perception are rooted mainly in light and acoustic comfort, while bad indoor air and odours are other contributors [90–92]. That means that hospital areas are not sufficiently serviced or separated from each other. Sound absorbers are missing for better acoustic comfort, and light comfort could be improved by making natural light more accessible and adjusting artificial light automatically.

Environmental Quality is where hospitals show the first apparent backlog. A central focus to improve a hospital's performance should be changing how hospitals manage their energy and making the hospital environment more comfortable for patients, staff, and visitors. Not only are consumers expecting higher comfort in healthcare, but they are also more concerned with the environment today. Increasing legislation on the supranational level towards climate neutrality can be expected. An existing initiative is, for instance, *Fit for 55*, a plan by the EU to reduce greenhouse gas emissions by 55% before 2030 [93].

Finally, 3. Organisational Quality is examined as the remaining macro-area. High scoring fields are 3.1 Patient Safety, 3.2 Survey and Monitoring, and 3.4 Logistics and Efficiency. The first criterion shows that hospitals generally take water impurity and clinical risk management seriously, yet score slightly below average in risk prevention strategies. In many hospitals, satisfaction monitoring and customer satisfaction programmes are in place to enable continuous improvement and the pursuit of excellence certification. Only monitoring indoor environmental quality is where clinics are not doing enough yet, as represented by indicator 3.2.2. All in all, the movement of goods and people is separated well enough to maintain hygiene, parking management systems are in place, and there is an effective physical connection between departments within the hospital.

Problematic areas in the participating clinics can be seen clearly in 3.6 Facility Management, 3.5 Technological Innovation, and 3.3 Future Proofing. These have to do with lacking maintenance strategies and budget management for facility management, barely existing technologies for efficiency, and biomedical device control even though digital innovation appears to work adequately [94]. Moreover, making the hospital ready for the future does not appear to be working well. Hospitals score low on spatial benchmark ratios,

opportunities to expand in the future, high flexibility, adaptability, and staying within the limit of the conventional lifespan of roughly 50 years [95]. Clinics are not systematically approaching facility management to increase outsourcing and reduce costs in that area. They could also increase their innovative capabilities by testing new ways to manage transport and further automate the management of pharmaceuticals [96]. Those findings are consistent with previously published knowledge about the problems and impact of social, environmental, and organisational sustainability on hospitals [59,97,98].

4.3. Applicability of SustHealth v2

The third research objective of the study concerns the applicability of SustHealth v2. This was important also to improve the existing state of the art of assessment tools and methodologies that show a lack of application of the same tool in different cases or contexts, in the sense of how hospitals in Germany cope with the questionnaire and how well the questions are formulated based on standard deviation. This is relevant also in the context of DSRM since the artefact (assessment tool) is effective and scalable in an actual situation and over the long-run. Thanks to the comparative case study, some dimensions emerged that need to be improved to increase efficiency and effectiveness in the future based on respondents' inputs. Survey format and length was the first area on which participants gave feedback. For several hospitals, the survey was too long; suggestions were to reduce the number of questions or change the content to enable faster responses. Regarding content and phrasing of questions, four main aspects emerged and are briefly reported below: First, many participants working in hospital quality management were grateful that several of their remarked problems were mentioned in the survey. Second, general feedback included that questions need to be amended or deleted as the content was not fully clear or answerable for respondents in time. Third, users cited the need for a "not applicable" option in several questions or the option that it has been resolved externally. Some participating hospitals did not have certain operations in their clinic but in a decentralised or independently managed location. The last observation was that the answers to some questions were only possible to estimate and not answer exactly. Finally, concerning question quality measured through standard deviation it emerged that 19 questions received the same answers by all the respondents (standard deviation of 0); this can be considered as an indicator that targets were either too simple or too difficult to reach, and may be dependent on the context conditions.

5. Conclusions

5.1. Research Outlook

Although the findings are aligned with research about hospital sustainability evaluation [14,52], this research purpose was not to create and validate an entirely new tool as much of the previous literature has done. Instead, the study tested an existing tool that differs from other evaluation forms in its holism, balance, and inclusion of the built environment. The findings demonstrate improvements compared to what is often found in literature, which is the low level of testing and validation of existing tools. This work addressed the research objectives by discussing patterns in sustainability of hospitals based on ownership type and number of patient beds. This investigation extends the body of research about evaluating sustainability in hospitals in high-income countries by adapting and testing the tool SustHealth v2 for the first time in Germany.

5.2. Study Strenghts, Limitations and Future Developments

This is the first time that a study has systematically analysed social, environmental, and organisational quality in operating hospitals in Germany. Therefore, those preliminary considerations provide a starting point from which to expand the analysis about sustainability compared to hospital characteristics. Even though clustering hospitals according to ownership and number of patient beds suggested interesting results, it is relevant to point out that due to the relatively limited sample, the size of each segmented cohort is tiny. This

has natural implications as the answers securely apply only to the sample itself and are not necessarily of universal nature, although they are aligned with current research in this field. Therefore, further application and testing is encouraged with wider sample sizes and in different contexts; multiple applications and comparison need to be considered as social, economic and physical factors (i.e., hospital size) may be reflected in the future results.

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