

# Key Performance Indicators to Benchmark Hospital Information Systems – A Delphi Study

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## Keywords

Benchmarking, hospital information systems, medical informatics, Delphi technique, quality indicators, key performance indicators, user satisfaction

## Summary

**Objectives:** To identify the key performance indicators for hospital information systems (HIS) that can be used for HIS benchmarking.

**Methods:** A Delphi survey with one qualitative and two quantitative rounds. Forty-four HIS experts from health care IT practice and academia participated in all three rounds.

**Results:** Seventy-seven performance indicators were identified and organized into eight categories: technical quality, software quality, architecture and interface quality, IT vendor quality, IT support and IT department quality, workflow support quality, IT outcome quality, and IT costs. The highest ranked indicators are related to clinical workflow support

and user satisfaction. Isolated technical indicators or cost indicators were not seen as useful. The experts favored an interdisciplinary group of all the stakeholders, led by hospital management, to conduct the HIS benchmarking. They proposed benchmarking activities both in regular (annual) intervals as well as at defined events (for example after IT introduction). Most of the experts stated that in their institutions no HIS benchmarking activities are being performed at the moment.

**Conclusion:** In the context of IT governance, IT benchmarking is gaining importance in the healthcare area. The found indicators reflect the view of health care IT professionals and researchers. Research is needed to further validate and operationalize key performance indicators, to provide an IT benchmarking framework, and to provide open repositories for a comparison of the HIS benchmarks of different hospitals.

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## 1. Introduction

Technological and medical evolution and organizational changes affect health care. As a consequence, health care has become increasingly more complex, and is today “characterized by more to know, more to do, more to manage, more to watch, and more people involved than ever before” [1].

To manage these increasing requirements, hospitals require an efficient hospital infor-

mation system (HIS). A HIS should support the information logistics within a hospital, making the appropriate information – the appropriate knowledge – at the appropriate time – at the appropriate location – the appropriate individuals – in an appropriate and usable form available [2]. In this sense, a HIS can be defined as the socio-technical subsystem of an enterprise, which consists of the information-processing activities and responsible human and mechanical com-

ponents in their information-processing roles [3]. The central task of HISs is to support a high-quality and cost-effective patient care [4].

As a result of the increasing importance of efficient information logistics, a systematic information management, comprising planning, directing and monitoring, becomes a central mission for hospitals [3]. While the planning and directing of information systems seem to be supported by several standards and guidelines (for example [3, 5–7]), the monitoring of information systems is often seen as more complex and not well supported [8, 9]. Monitoring comprises, among others, the definition and application of those criteria that should reflect the quality and efficiency of information logistics. In this sense, monitoring stands in close relation with a systematic benchmarking of HISs.

According to the Joint Commission [10], benchmarking can be defined as the “continuous measurement of a process, product, or service compared to those of the toughest competitor, to those considered industry leaders, or to similar activities in the organization in order to find and implement ways to improve it”. The Joint Commission differentiates between internal benchmarking (similar processes within the same organization are compared) and competitive benchmarking (organization’s processes are compared with best practices within the industry).

Benchmarking in general comprises the choice of an appropriate target, the definition of the related performance indicators, and the collection of the relevant data that can then be used for comparison purposes [11].

There exist several approaches to develop performance indicators for hospitals. For example, the Joint Commission’s Annual Report on Quality and Safety 2008 provides evidence of U.S. hospitals’ performance regarding National Patient Safety Goals [12].

This report describes how well hospitals follow the pre-defined treatment guidelines.

For benchmarking the information systems of a hospital, fewer approaches seem to exist. The information management standards of JCAHO [13] define ten major standards with several sub-standards, in turn focusing on the general issues of information management within a hospital (including, for example, usage of standardized codes and classifications, availability of a complete medical record, or access to knowledge resources). These standards, however, do not define the objective, quantitative indicators that can be used for benchmarking.

Health IT researchers, therefore, have developed quantitative instruments trying to assess the quality of a HIS, based on user surveys [14, 15]. These instruments, however, do not comprise objective performance indicators.

Other approaches that define the IT performance indicators are COBIT (for the planning, acquisition, operation, support and monitoring of IT) [16] and ITIL (for the planning and monitoring of IT service management) [6]. Both provide objective and subjective performance indicators (for example, percentage of IT projects that can be derived from the IT strategy, percentage of users satisfied with IT training, number of user complaints, costs of IT non-compliance). These approaches, however, primarily focus on the IT operation and IT support quality and not on the overall HIS.

Summarizing, while several established attempts exist to define the indicators for the quality and performance of hospitals in general and of the IT management processes, systematic approaches to objectively benchmark the quality of HISs are lacking. Consequently,

in most hospitals, no regular HIS monitoring activities based on the objective and quantified assessment of HIS quality are conducted. Overall, it seems necessary to first define what useful HIS performance indicators are, before adequate validated methods to measure them can be developed.

The **objective of the present paper** is to develop a prioritized list of the useful performance indicators for HISs, based on a Delphi-based survey of HIS experts. The study questions were:

- What are and what are not useful performance indicators for HISs?
- Who should carry out HIS benchmarking, and when?
- Are there any HIS benchmarking activities being performed in hospitals?

## 2. Methods

### 2.1 The Approach: A Delphi Study

We decided to use the Delphi method to address our study questions. The Delphi method allows for a systematic, interactive, iterative collection of expert opinions [17, 18]. After each round, the experts receive an anonymous summary of all the experts' opinions from the previous round. Afterwards, the participants are encouraged to revise their earlier answers in view of the replies of the other experts. Compared to other methods, such as group discussion or expert interviews, a Delphi study enables the inclusion of a larger number of experts, in which the experts are allowed to revise their opinions in view of the other experts' opinions [19]. From the four different types of Delphi studies described by Häder [20], we

chose Type 3 (► Fig. 1), comprising one qualitative and two quantitative rounds:

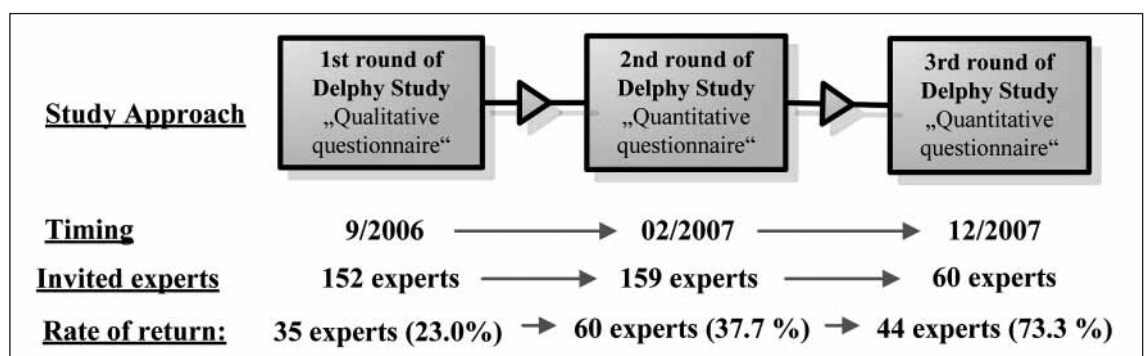
1. First qualitative round: A written survey with five open-ended questions was used to collect ideas for the useful performance indicators for HIS benchmarking.
2. Second quantitative round: Based on the results of the first round, a standardized questionnaire with close questions was developed, in turn requesting the experts to rate the importance of each proposed indicator on a 4-point Likert scale (21).
3. Third quantitative round: The results of the second round were sent back to the experts, in turn requesting them to re-consider their voting in light of the opinions of the overall expert panel.

The first round was submitted to the expert panel on September 2006. The following two quantitative rounds started February 2007 and were finalized December 2007.

Our Delphi study was conducted based on an online questionnaire (developed with the help of the software 2ask.at).

### 2.2 Selection of the Appropriate Expert Panel

We established a panel with experts from Austria, Germany and Switzerland. For this, we invited 152 experts, who were from the university field of medical informatics (typically researchers also involved in the IT management of the university hospitals) or from practical hospital-based health care IT (for example CIOs, head of the IT department of a hospital, etc.). This combination should help to combine the opinions of experts from both research and practice.



**Fig. 1**  
Steps of the Delphi study

### 2.3 First Round: Qualitative Survey

The first qualitative round focusing on “What could be the useful performance indicators for HIS?” was used to collect ideas and to obtain a broad range of opinions. In this first round, we contacted 152 experts and posed the following questions to them in free-text form:

1. Please provide at least eight criteria or performance indicators that you find useful to assess a hospital information system (HIS) (for example criteria in reference to satisfaction, IT diffusion, functionality, architecture, interfaces, etc.).
2. Please provide at least three key performance indicators that you do NOT find useful to assess a HIS.
3. Which departments or persons should be responsible – in your opinion – for HIS benchmarking?
4. When should the HIS benchmarking be carried out (for example after certain events, in regular intervals, etc.)?
5. Is there any form of HIS benchmarking in your current organization? If yes, in which form?

The free-text answers to those questions were systematically analyzed by using qualitative content analysis [22]. The answers were coded based on a system of categories. First, we defined the dimension of the categories and the level of abstraction and we determined the screening criteria for each category. In the next step, we went line-by-line through the material, in which we assigned each text passage to a category (subsumption). If a text passage did not match the established categories, we defined a new category (inductive categorization). After passing 50% of the material, the whole system of categories was revised and adapted with regard to the subject and aims of the survey, before finalizing the analysis. The resulting list

of categories reflected the possible performance indicators for HIS. The overall categorization was done by two researchers; any differences in opinions were resolved by discussion.

### 2.4 Second Round: Quantitative Survey (Part 1)

Based on the results of the first round, a standardized questionnaire was developed that presented the list of proposed indicators for HIS benchmarking. We requested the experts to rate the importance of each indicator, offering them a four-point Likert scale (very important – rather important – rather not important – not important).

### 2.5 Third Round: Quantitative Survey (Part 2)

The results of the standardized questionnaire were analyzed by using descriptive statistics and then were sent back to the experts. The experts were then asked to reconsider their choice in light of the aggregated results, offering them the identical questionnaire as in the second round. The descriptive data analysis for the second and third round was realized by SPSS 13.0.

## 3. Results

### 3.1 First Round: Qualitative Survey

From the 152 invited experts, 35 experts responded (response rate: 23%). The distribution of the experts is shown in ►Table 1.

From those 35 experts, we received more than 400 proposals for the performance indicators for HIS benchmarking. By using

qualitative content analysis, we aggregated these expert answers into 77 items, organized into eight categories: technical quality, software quality, architecture and interface quality, IT vendor quality, IT support and IT department quality, workflow support quality, IT outcome quality, IT costs (for details of the items in each category see ►Appendix).

Experts also provided 74 comments on the indicators that they did *not* find useful. The most significant comments were as follows (in brackets is the number of experts commenting on the given topic, in descending order):

1. Acquisition costs for hardware and software, IT budget or IT costs per user are not useful indicators, if they are not related to the outcome obtained (n = 10).
2. Availability of specific types of computer systems, operation systems or database systems are not useful as indicators (n = 9).
3. The number of computer systems or the number of IT staff members as the only indicator is not useful (n = 6).
4. Only a combination of indicators and a combination or point of views (for example different user groups) can provide a good picture of HIS quality, in which individual indicators may be misleading (n = 5).
5. The usage of technological buzzwords such as “open”, “component-based”, “SOA”, “workflow engine” does not say much about the efficiency of patient care and is, therefore, not useful (n = 4).
6. The overall HIS architecture (monolithic, distributed, etc.) and the software architecture (3-tier architecture, etc.) are not good criteria, as “there are good and bad HISs, independent of the architecture” (n = 4).
7. Finally, the popularity of an IT product or the number of installations of a given IT software product are also not good indicators for HIS quality (n = 4).

### 3.2 Second Round: Quantitative Survey (Part 1)

In the second round, we invited 159 experts (108 experts of hospital/health organization and industry/consulting companies and 51 experts of research organizations or universities). We invited the entire expert panel of the first (n = 152) round and seven additional

Affiliation of the participants	First round	Second round	Third round
Hospital/health organization	20 (57.1 %)	32 (53.3 %)	22 (50%)
Research organizations/university	13 (37.1 %)	25 (41.7 %)	20 (45.5%)
Industry/consulting companies	2 (5.7 %)	3 (5%)	2 (4.5%)
<b>Sum</b>	<b>35 (100%)</b>	<b>60 (100%)</b>	<b>44 (100%)</b>

**Table 1**  
Number of experts participating in each of the three rounds of the Delphi study, and their affiliations

experts. Sixty experts answered in this second round (rate of return = 37.7 %). The distribution of the experts is shown in ► Table 1.

The questionnaire that the experts received contained 77 questions, reflecting the 77 performance indicators identified in the first qualitative round (see ► Appendix 1 for the complete list of questions).

### 3.3 Third Round: Quantitative Survey (Part 2)

In this last round, we invited the 60 experts that participated in the second round, in which 44 of them responded (rate of return: 73.3%). The distribution of the experts is shown in ► Table 1. The questionnaire contained the same 77 questions as in the second round (► Appendix).

► Figure 2 shows the results for the 15 indicators judged as “very important” by at least 70% of the participants in this round. The detailed results for all 77 indicators are shown in the ► Appendix. The overall inter-rater reliability for all items is 0.35, calculated based on the formula provided by Gwet [23].

### 3.4 Who Should Perform Benchmarking, and When?

We asked the experts as to which departments or persons should be responsible for HIS benchmarking. From the 35 participants, we received 35 open-ended answers that we aggregated. ► Table 2 shows the results.

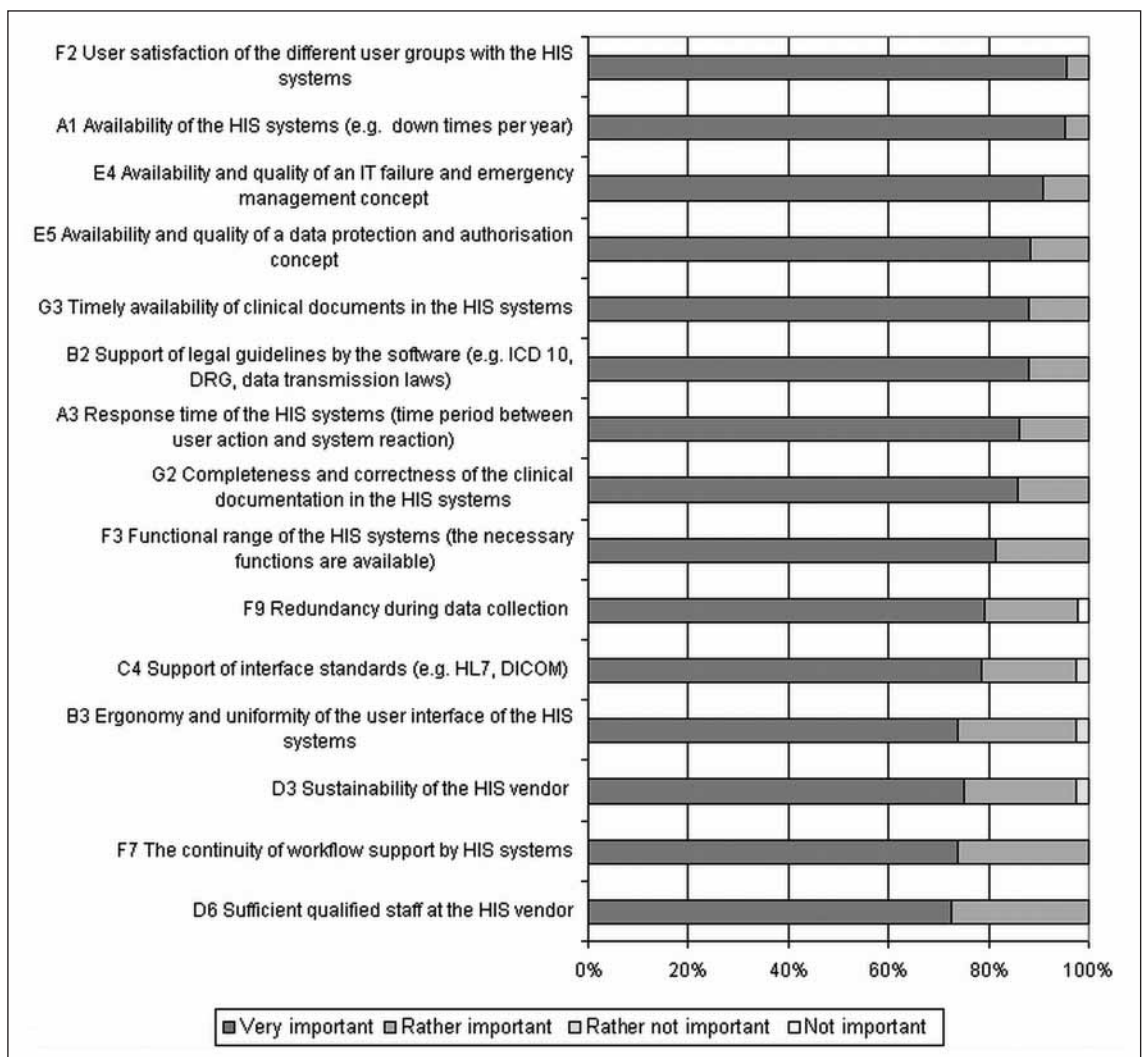
We asked “when should the HIS benchmarking be carried out?”. Here, we received 31 answers (► Table 3).

### 3.5 Do Hospitals Have HIS Benchmarking?

As a final question, we asked whether the experts have any form of HIS benchmarking in their respective institutions. Here, we received answers from 31 experts (► Table 4).

## 4. Discussion

The aim of this Delphi study was to develop a comprehensive approach of the quantitative performance indicators in order to benchmark hospital information systems.



**Fig. 2** Results for the 15 performance indicators that more than 70% of the 44 experts judged as “very important” (results of the third round of the Delphi study)

## 4.1 Answers to the Study Questions

### 4.1.1 What Are Useful HIS Performance Indicators?

Our study developed a list of 77 performance indicators that are suitable for HIS benchmarking. Of those 77 indicators, 15 were regarded by more than 70% of the experts as “very important” (► Fig. 2). From those 15 most important items, only three are related to technical issues, while five are related to clinical workflow support, three to IT management issues, and two to user satisfaction and user interface design (► Fig. 2). HIS quality seems thus to be understood in a strongly user- and workflow-oriented way. This is supported by the finding that the item with the highest support by the experts was “user satisfaction with HIS systems”.

Key performance indicators need to be operationalized to be of use. When looking at the list of indicators (► Appendix), the majority seems fairly well quantifiable (for example, indicators focusing on time, number, effort or costs). However, the indicators for workflow support quality may be much more difficult quantifiable (e.g. this may explain why, despite the high importance of this issue, no established benchmarking frameworks for health IT exist).

The opinions of the experts were quite stable between the second and third round. Only for two items was their median changed (item H9 “Costs of clinical documentation” changed from *rather important* to *rather not important*, and item D2 “Participation in standard setting bodies” changed from *rather important* to *rather not important*).

Our group of experts comprised both researchers as well as hospital IT staff members. A subgroup analysis revealed largely comparable opinions on the significance of all indicators between those two groups, with three exceptions: The hospital IT experts judged the two performance indicators C2 “Number of interfaces” and E11 “Training effort per user” higher than the experts from research. This may reflect the fact that interface management and training organization make up a larger part of their work. On the other side, the researchers judged the indicator G1 “Patient satisfaction with patient care” higher than the hospital IT experts. The overall

agreement of both groups may reflect that all were health IT specialists, either from practice or academia. Other groups such as users and hospital administration may have completely different view. Their view, however, has not been assessed in this study.

### 4.1.2 What Are not Useful HIS Performance Indicators?

The experts stated that individual IT cost indicators, indicators on the number or type of

hardware or software systems, buzzword-oriented indicators (“SOA”) or indicators on the type of HIS architecture are not useful. These indicators seem to not provide sufficient information on the performance of a HIS and therefore should only be seen in combination with other indicators.

### 4.1.3 Who Should Carry out HIS Benchmarking?

The experts had different opinions (► Table 2): One-third of the experts favored an interdisciplinary group of representatives of all the relevant professions (IT users, IT department, and hospital management). One-fourth of the experts either favored the IT department as responsible for HIS benchmarking, or the hospital management. The advantage of an interdisciplinary group is that the different points of view can be integrated when developing benchmarking criteria – the need to combine indicators that reflect different points of view was mentioned in several comments. On the other side, the IT department has the best access to the needed data, but is not independent, in which the benchmarking outcome may be biased. Therefore, some experts favored the hospital management to be responsible, or they request support from external, independent experts. Summarizing, an interdisciplinary group of all stakeholders, led by hospital management and supported by external experts, may be an appropriate way to organize benchmarking.

**Table 2** Answers to the question: Who should be responsible for HIS benchmarking? (n = 35 experts)

	n	%
Only CIO or IT department	9	25.7%
Only hospital management, controlling or quality management	8	22.9%
Only user representatives (for example a physician, a ward manager) as the process owner	2	5.7%
Interdisciplinary group of users (physicians, nurses, administrative staff) together with the management and IT staff	12	34.3%
External, independent persons (for example consultants, universities) as supporters	4	11.4%
<b>Total</b>	<b>35</b>	<b>100%</b>

**Table 3** Answers to the question: “When should the HIS benchmarking be carried out?” (n = 31 experts)

	n	%
Quarterly	3	9.7%
Annually	12	38.7%
Any 2–3 years	4	12.9%
At defined events (HIS updates, changes in HIS architectures, organizational changes)	5	16.1%
Regularly (for example yearly) and also at defined events (for example after IT introduction)	5	16.1%
Short reports quarterly, more detailed (strategic) reports annually	2	6.5%
<b>Total</b>	<b>31</b>	<b>100%</b>

### 4.1.4 When Should the HIS Benchmarking Be Performed?

Experts stated that both regular benchmarking as well as benchmarking after defined events (for example introduction of a new IT system, larger updates, or new legal regulations) are necessary (► Table 3). For regular benchmarking, most experts favored annual benchmarking; probably as the effort for shorter periods seems too high. Two experts proposed to combine shorter reports on a quarterly basis with more detailed annual reports. Some comments indicated that it is helpful when the data for HIS benchmarking can be derived automatically, for example by using data warehousing approaches.

#### 4.1.5 Do Hospitals Have HIS Benchmarking?

Two-thirds of the experts stated that no systematic benchmarking is carried out in their institutions, or that it is only performed in informal ways (► Table 4). Seven experts stated that benchmarking is performed at least partly. Indicators that are already in use comprise IT usage, IT coverage, data quality, user satisfaction, or number of discharge letters or diagnosis per day. Some experts also mentioned dedicated evaluation or impact studies. Here, however, it should be noted that this would typically not be considered as benchmarking, as this comprises the regular assessment of a pre-defined set of standardized indicators.

#### 4.2 Strengths and Weaknesses of the Study

For the development of performance indicators, we used the Delphi study Type 3 with a combination of a qualitative and two quantitative rounds. The qualitative round helped to explore first ideas on the indicators, in which the quantitative surveys served to obtain a quantitative opinion from the expert panel. This combination of qualitative and quantitative methods is an example of multi-method triangulation, where the qualitative part aims at identifying the relevant variables, which are then thoroughly studied in the quantitative part [24].

Forty-four experts participated in all three rounds of our study. Reliable outcomes of a Delphi study can already be obtained by an even smaller number of participants, as for example Akins [25] showed, therefore, this number seems adequate to attain valid conclusions. However, a formal validation on the completeness of the indicator list was not performed.

The expert panel consisted of experts from the field of academia and hospital IT practice. Most participants had leading positions within their institutions and extensive experience in health IT (for example professor for health informatics, CIO, head of IT department, IT project manager). Around half of the participants from academia also had responsibilities in the IT management of their local university hospitals (for example as a member of the

**Table 4** Answers to the question: Is there any form of HIS benchmarking in your organization? (n = 31 experts)

	n	%
No	16	51.6%
Planned or in development	4	12.9%
Not in a systematic way, but for example by informal user feedback or informal user interviews	4	12.9%
Yes or yes, partly:	7	22.6%
<ul style="list-style-type: none"> <li>• Since 2001, comprehensive benchmarking accordingly based on defined criteria, results available to all users</li> <li>• Yearly report on usage, coverage, data quality, plus regular user satisfaction and impact studies</li> <li>• During system acquisition according to defined user criteria</li> <li>• Number of discharge letters/day, number of diagnoses/day, number of appointments/day</li> <li>• User survey by external company</li> <li>• Regular reports in IT project steering committees and IT strategy committees</li> <li>• During system acquisition, use of a requirement catalog</li> </ul>		
<b>Total</b>	<b>31</b>	<b>100%</b>

IT strategic committee), thus this expert panel represented experts with strong practical health IT experience. We feel that this combination is an adequate representation of the needs and requirements of hospital IT with regard to HIS benchmarking.

Different groups (such as IT experts, hospital administration, clinicians, patients) may have different perceptions of useful HIS performance indicators. We did not include a larger group of user representatives (for example physicians, nurses, or administration staff). Users may focus on different aspects, for example, they may concentrate on the quality of IT support for their respective tasks. So, probably, a Delphi study with those groups may have found a stronger emphasis on indicators from categories F (workflow supports) and G (IT outcome quality), and

less emphasis on technical issues such as HIS architecture.

Our panel consisted of experts from Austria, Germany and Switzerland, with an overrepresentation of Austrian participants (from the 44 participants in the third round, 21 were from Austria, 17 from Germany, and 6 from Switzerland). These countries have several similarities with regard to language, culture and organization in health care. The results may not be transferable to other countries with different organizational or cultural systems.

The return rates were satisfactory, with 23% in the first qualitative round, 37.7% in the second round and 73.3% in the third round. Those experts that already participated in the first round were also sufficiently motivated to participate in further rounds.

One limitation of our study was that the understanding of the term “HIS benchmarking” could vary between the experts. First, a “HIS” can be understood as the overall information processing subsystem of a hospital (i.e. including the paper-based tools and the workflow), as only the computer-based software systems, or only as the clinical systems. In addition, the term “benchmarking” may be understood as a regular assessment of quantitative performance criteria, but also as a synonym for “IT evaluation”, which would include single, dedicated IT impact and evaluation studies. This different understanding of those terms is partly reflected in the answers and comments of the experts. While we attempted to describe all the performance indicators in an unambiguous way, this may not have been successful for the entire list. This partly reflects the ongoing discussion of clear definitions of the major health informatics terms (see for example [26]).

#### 4.3 Results in Relation to Other Studies

Many approaches for IT benchmarking exist, which often focus on cost issues [27]. Our study shows that costs are just one important issue among several other aspects such as workflow support, user satisfaction or outcome quality. This supports the notion of IT governance with IT as a business enabler – and not only as a cost driver – also for health care organizations [28]. In fact, the most important quality indicator that our experts de-

financed was user satisfaction. This is supported by the vast literature on this issue, stating in turn that low user acceptance can lead to user frustration and project failure [29–32]. While COBIT [27] and ITIL [6] assess processes and systems from the point of view of the IT, our results highlight the users' point of view. For example, COBIT defines around 340 performance indicators for IT management, concentrating on aspects such as the quality of IT service and IT support, which primarily corresponds to our categories A (technical quality) and E (quality of IT support and IT department), and do not cover for example outcome quality or quality of workflow supports. This also means that, in turn, important technical issues such as maintainability and expandability of the IT systems are not reflected in our results.

Also focusing on the users' point of view, Otieno et al. [11] and Ribière [33] developed and validated survey-based instruments for benchmarking HIS quality. Both groups based their primary selection of items on a systematic literature survey. We chose another approach, collecting and prioritizing the opinions of experts directly working in this field by a systematic Delphi approach.

Other authors have presented benchmarking approaches focusing on objective HIS data. For example, Dugas et al. [34] presented a benchmarking system focusing on the number of discharge letters per month, the number of appointments made per day, etc. These numbers are easy to gather and aggregate. In our survey, however, those data were not among the list of the most important items, probably as those indicators alone do not reflect the HIS quality very well. Müller and Winter [8] presented a project where those indicators focusing on system usage were quarterly extracted and presented to the hospital staff. Aspects other than system usage were not covered.

We structured our items according to a qualitatively developed system of eight categories. When we understand the hospital information systems as a service of an IT department that is delivered to the users as customers, we could also adopt the Balanced Scorecard (BSC) [35] approach to the structure of the items. From this point of view, our 77 indicators are related to all four BSC dimensions: the internal business process perspective (most of categories A, B, C, D and E),

the customer perspective (most of categories F and G), the financial perspective (category H), and the learning-to-growth perspective (partly reflected in C and E, for example the flexibility of the overall IT architecture, or qualifications of the IT staff).

James Martin [36] identified four major levels of business processes: the operational level, the monitoring and control level where the correct running of processes is monitored, the planning and analysis level where correct processes are defined, and the strategic level. In this pyramid, benchmarking is linking the strategic level to the planning and analysis level by helping to transform strategic objectives into operation. Benchmarking is thus an activity to be conducted in regular, though larger intervals (for example quarterly, yearly), which corresponds to our experts' opinion.

#### 4.4 Meaning and Generalizability of the Study

Our results present, to our knowledge, the first attempt to systematically develop HIS performance indicators by a Delphi approach. The list of indicators was quite stable in our Delphi study, which reflects the many different issues (technology, data quality, workflow support, IT management) that should be tackled by HIS benchmarking projects. Obviously, while the list may not be exhaustive, it seems infeasible for a hospital to include all of those indicators in a HIS benchmarking project. Instead, a thorough selection based on the benchmarking objectives, taking into account both the feasibility and usefulness of the chosen indicators, may be carried out in an interdisciplinary group.

#### 4.5 Unanswered and New Questions

The developed list of potential HIS benchmarking criteria can be seen as a starting point for the development of a HIS benchmarking framework. This framework should provide performance indicators for different points of view (such as IT management, users, or patients). What has to be done now is to complete the list by adding views from other groups. Then, the most important indi-

cators should be selected to develop clear definitions, operationalization, target values, and adequate instruments [27]. For certain indicators, instruments have already been developed, such as for user satisfaction [14, 33, 37], usage of systems [38], usability evaluation [39], quality of HIS architecture [40], quality of IT management [27], and composite approaches [11]. Based on the defined indicators, a health IT benchmarking framework may then be developed.

Benchmarking does not only comprise the definition and measurement of indicators, but also a comparison to the best competitor. Therefore, open repositories need to be developed to gather HIS benchmarking data from various hospitals, and to provide an (anonymous) comparison with other hospitals. This would allow the IT management to assess the strengths and weaknesses of its respective hospital information system, and help to systematically improve it.

## 5. Conclusion

Albert Einstein is often quoted as saying “not everything that can be measured is important, and not everything that is important can be measured” (for example by [41]). HIS management is thus advised to identify a subset of items that seem to best represent local HIS performance. In addition, besides for pure quantitative benchmarking, further important insight into HIS quality may be achieved from more qualitative approaches, which help to complement the picture, to explain the quantitative findings, and to propose improvements [24]. Given this constraint, HIS benchmarking can be seen as one important contribution to IT governance, in turn helping to professionally manage and steadily improve hospital information systems.

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## Appendix

Importance of the HIS performance indicators, as judged by 44 experts (third round of the Delphi study). Median values are highlighted in grey.

Cat.	Item	N valid	Very important (Valid %)	Rather important (Valid %)	Rather not important (Valid %)	Not important (Valid%)
<b>A</b>	<b>Technical Quality</b>					
A 1	Availability of the HIS systems (e.g. down times per year).	42	40 (95.2%)	2 (4.8%)	–	–
A 2	Performance of the HIS systems (amount of data that is processed within a given time period)	43	21 (48.8%)	21 (48.8%)	1 (2.3%)	–
A 3	Response time of the HIS systems (time period between user action and system reaction)	43	37 (86.0%)	6 (14.0%)	–	–
A 4	Duration of user authentication (time until the functions are available)	42	27 (64.3%)	13 (31%)	2 (4.8%)	–
A 5	Number of new hardware acquisitions per year	42	1 (2.4%)	10 (23.8%)	27 (64.3%)	4 (9.5%)
A 6	Hardware equipment (e.g. sufficient number, sufficient performance)	43	8 (18.6%)	31 (72.1%)	4 (9.3%)	–
A 7	Data loss rate and the restore time of the HIS systems per year	42	27 (64.3%)	13 (31%)	2 (4.8%)	–
A 8	Independence and mobility of the tools for data entry and information retrieval (e.g. notebook, tablet PC, PDA, etc.)	42	5 (11.9%)	24 (57.1%)	12 (28.6%)	1 (2.4%)
<b>B</b>	<b>Software Quality</b>					
B 1	Functional coverage of the HIS software	43	11 (25.6%)	29 (67.4%)	3 (7.0%)	–
B 2	Support of legal guidelines by the software (e.g. ICD 10, DRG, data transmission laws)	42	37 (88.1%)	5 (11.9%)	–	–
B 3	Ergonomics and uniformity of the user interface of the HIS systems as well as intuitive usage	42	31 (73.8%)	10 (23.8%)	1 (2.4%)	–
B 4	Time needed for standard functions (e.g. patient admission) – how many “clicks” are necessary	42	25 (59.5%)	16 (38.1%)	1 (2.4%)	–
B 5	Possibility to adapt software to the local conditions, also by the customer (e.g. mean effort for the initial adaptation)	43	25 (58.1%)	15 (34.9%)	3 (7.0%)	–
B 5	Level of the maturity of the software, as indicated by the number of service calls of the IT department to the HIS vendor	42	14 (33.3%)	27 (64.3%)	–	1 (2.4%)
B 7	Effort for updates/upgrades of the software (e.g. duration, instability)	43	9 (20.9%)	23 (53.5%)	11 (25.6%)	–
B 8	Support of the market standards (e.g. standards of development and database system, operating systems, client software)	42	9 (21.4%)	24 (57.1%)	8 (19%)	1 (2.4%)
<b>C</b>	<b>Architecture and Interface Quality</b>					
C 1	Homogeneity and heterogeneity of the HIS systems	44	13 (29.5%)	24 (54.5%)	7 (15.9%)	–
C 2	Number of interfaces between the HIS systems	43	2 (4.7%)	30 (69.8%)	10 (23.3%)	1 (2.3%)
C 3	The relation of HIS systems connected by interfaces to those without interfaces	42	7 (16.7%)	23 (54.8%)	10 (23.8%)	2 (4.8%)
C 4	Support of interface standards (e.g. HL7, DICOM)	42	33 (78.6%)	8 (19%)	1 (2.4%)	–
C 5	Number of clinical departments that use an own subsystem for documentation	42	4 (9.5%)	23 (54.8%)	12 (28.6%)	3 (7.1%)
C 6	Time effort and costs when connecting subsystems that have standard interfaces	43	12 (27.9%)	26 (60.5%)	5 (11.6%)	–
C 7	Number of double interfaces (e.g. one message is sent directly to two application systems)	41	5 (12.2%)	18 (43.9%)	15 (36.6%)	3 (7.3%)
C 8	Number of external interfaces, to illustrate the support of co-operative patient care (e.g. query of medical patient documents by other health care institutions)	42	6 (14.3%)	24 (57.1%)	11 (26.2%)	1 (2.4%)

Cat.	Item	N valid	Very important (Valid %)	Rather important (Valid %)	Rather not important (Valid %)	Not important (Valid%)
C 9	Level of service orientation of the architecture (IT Infrastructure aligned to business processes)	44	13 (29.5%)	22 (50.0%)	8 (18.2%)	1 (2.3%)
C 10	Compatibility of the whole IT infrastructure (e.g. operating systems, application systems)	43	17 (39.5%)	25 (58.1%)	1 (2.3%)	–
<b>D</b>	<b>IT Vendor Quality</b>					
D 1	References of the HIS vendor	40	6 (15%)	31 (77.5%)	3 (7.5%)	–
D 2	Participation of the HIS vendor in standard setting bodies (e.g. HL7)	40	5 (12.5)	14 (35%)	18 (45%)	3 (7.5%)
D 3	Sustainability of the HIS vendor (e.g. assured further development)	40	30 (75%)	9 (22.5%)	1 (2.5%)	–
D 4	Implementation and operation support and a good update and bug fixing management by the HIS vendor	40	27 (67.5%)	13 (32.5%)	–	–
D 5	Preparation of HIS handbooks and HIS trainings by the HIS vendor	40	4 (10%)	32 (80%)	4 (10%)	–
D 6	Sufficient qualified staff at the HIS vendor (for development, support and adaption)	40	29 (72.5%)	11 (27.5%)	–	–
<b>E</b>	<b>IT Support and IT Department Quality</b>					
E 1	Number of IT staff in relation to the number of users, beds, outpatient cases and workstations	43	12 (27.9%)	24 (55.8%)	7 (16.3%)	–
E 2	Qualification of the staff in the IT department	43	26 (60.5%)	17 (39.5%)	–	–
E 3	Availability of process definitions in the IT department for error management, updates, documentation, etc.	41	8 (19.5%)	27 (65.9%)	6 (14.6%)	–
E 4	Availability and quality of an IT failure and emergency management concept	43	39 (90.7%)	4 (9.3%)	–	–
E 5	Availability and quality of a data protection and authorisation concept	43	38 (88.4%)	5 (11.6%)	–	–
E 6	Number of data protection violations per year	42	11 (26.2%)	25 (59.5%)	6 (14.3%)	–
E 7	Number of hotline calls per user and the mean duration of incident and problem solving	43	7 (16.3%)	33 (76.7%)	3 (7%)	–
E 8	Number of calls that are <u>not</u> incoming through hotline or first-level-support	42	6 (14.3%)	23 (54.8%)	11 (26.2%)	2 (4.8%)
E 9	Number of calls that are successfully solved within a set timeframe (e.g. 6 hours)	42	13 (31%)	23 (54.8%)	5 (11.9%)	1 (2.4%)
E 10	Overall number of HIS user/user groups and number of new HIS user/year that must be supported	42	5 (11.9%)	25 (59.5%)	11 (26.2%)	1 (2.4%)
E 11	Training effort per user.	43	8 (18.6%)	29 (67.4%)	6 (14.0%)	–
E 12	Number of successful completed HIS projects	41	6 (14.6%)	28 (68.3%)	7 (17.1%)	–
E 13	Percentage of discontinued IT projects in relation to all the IT projects	41	3 (7.3%)	22 (53.7%)	13 (31.7%)	3 (7.3%)
E 14	Fulfilment of service levels within the service level agreements (SLA)	39	4 (10.3%)	25 (64.1%)	10 (25.6%)	–
<b>F</b>	<b>Workflow Support Quality</b>					
F 1	Number of departments, users, professional groups that use the HIS systems routinely, and the respective frequency of use	43	13 (30.2%)	26 (60.5%)	4 (9.3%)	–
F 2	User satisfaction of different user groups with the HIS systems	44	42 (95.5 %)	2 (4.5 %)	–	–
F 3	Functional range of the HIS systems (the necessary functions for administration and patient care are available)	43	35 (81.4%)	8 (18.6%)	–	–
F 4	Coverage of the functionality desired by the users	44	24 (54.5%)	20 (45.5%)	–	–

Cat.	Item	N valid	Very important (Valid %)	Rather important (Valid %)	Rather not important (Valid %)	Not important (Valid%)
F 5	Level of information of the user about the provided functionality of the HIS systems	44	11 (25.0%)	32 (72.7%)	1 (2.3%)	–
F 6	IT sophistication with regard to the functions (relation of the IT supported tasks to the non-IT supported tasks)	43	15 (34.9%)	25 (58.1%)	3 (7.0%)	–
F 7	The continuity of workflow support by HIS systems	42	31 (73.8%)	11 (26.2%)	–	–
F 8	Functional redundancy (number of enterprise functions that are supported by more than one system)	43	9 (20.9%)	18 (41.9%)	13 (30.2%)	3 (7.0%)
F 9	Redundancy during data collection (must the same data item be documented more than once?)	43	34 (79.1%)	8 (18.6%)	–	1 (2.3%)
F 10	Time needed for clinical documentation per staff and time period	43	22 (51.2%)	18 (41.9%)	2 (4.7%)	1 (2.3%)
F 11	Number of discharge letters, medical reports, appointments, orders, diagnoses/procedures, operation reports, pictures per period in relation of clinical key data (number of cases)	43	15 (34.9%)	22 (51.2%)	6 (14%)	–
F 12	Amount of departmental documentation that is regularly documented in the (main) HIS system	42	4 (9.5%)	24 (57.1%)	14 (33.3%)	–
F 13	Completeness of the electronic patient record in relation to the total number of patient documents (relation of the electronic documents to the remaining paper-based documents)	42	22 (52.4%)	9 (45.2%)	1 (2.4%)	–
F 14	Coverage of medical knowledge bases	42	1 (2.4%)	21 (50.0%)	18 (42.9%)	2 (4.8%)
F 15	Frequency of the usage of medical knowledge bases	43	1 (2.3%)	15 (34.9%)	23 (53.5%)	4 (9.3%)
<b>G</b>	<b>IT Outcome Quality</b>					
G 1	Patient satisfaction with patient care	41	24 (58.5%)	16 (39%)	1 (2.4%)	–
G 2	Completeness and correctness of the clinical documentation in the HIS systems	42	36 (85.7%)	6 (14.3%)	–	–
G 3	Timely availability of clinical documents in the HIS systems	42	37 (88.1%)	5 (11.9%)	–	–
G 4	Contribution of the HIS systems to the hospitals' success	43	23 (53.5%)	16 (37.2%)	4 (9.3%)	–
G 5	Contribution of the HIS systems to the strategic goals of the medical, nursing and administrative management	41	27 (65.9%)	13 (31.7%)	1 (2.4%)	–
G 6	Duration between the patient discharge and completion of the discharge letter and accounting	42	16 (38.1%)	21 (50%)	4 (9.5%)	1 (2.4%)
<b>H</b>	<b>IT Cost</b>					
H 1	Total costs of the HIS systems (acquisition, operation, IT staff, training etc.) per year	43	11 (25.6%)	25 (58.1%)	6 (14.0%)	1 (2.3%)
H 2	Total costs of the HIS systems in relation to the hospital turnover	40	12 (30%)	21 (52.5%)	7 (17.5%)	–
H 3	Total costs of the HIS systems in relation to the offered functionality and usage in the departments	42	13 (31%)	26 (61.9%)	3 (7.1%)	–
H 4	Cost effectiveness of the HIS systems (cost versus benefit)	42	25 (59.5%)	13 (31%)	3 (7.1%)	1 (2.4%)
H 5	Operating costs of the HIS systems per year	42	14 (33.3%)	24 (57.1%)	4 (9.5%)	–
H 6	Monetary benefits by the HIS systems (e.g. reduction of staff, paperwork)	41	10 (24.4%)	22 (53.7%)	7 (17.1%)	2 (4.9%)
H 7	Costs of IT hardware in relation to IT support staff	40	5 (12.5%)	19 (47.5%)	14 (35%)	2 (5%)
H 8	Costs of IT software and IT diffusion in relation to the number of users	42	6 (14.3%)	24 (57.1%)	11 (26.2%)	1 (2.4%)
H 9	Costs of clinical documentation in relation to the total income of the hospital	41	4 (9.8%)	14 (34.1%)	20 (48.8%)	3 (7.3%)
H 10	Yearly increase in IT investments for HIS systems	42	6 (14.3%)	25 (59.5%)	11 (26.2%)	–