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Assessment of Smartness Status in Public Hospitals and Its Relationship with Characteristics and Performance Indicators

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Abstract

Background: The need for smartification is increasingly recognized in public hospitals, making it crucial to identify the current status, gaps, and factors influencing hospital smartness.

Objectives: This study aimed to assess the smartness status of public hospitals and investigate its correlation with hospital characteristics and performance indicators.

Methods: This descriptive-analytical cross-sectional study was conducted in seven public hospitals in Alborz Province, Iran, during 2023 - 2024. We assessed the characteristics and performance indicators of the hospitals using a researcher-developed questionnaire and evaluated their smartness status with the standardized "Smart Hospital Evaluation" checklist. Data analysis was performed using SPSS24 software, utilizing independent *t*-tests, Pearson's correlation, Spearman's correlation, and analysis of variance (ANOVA) tests.

Results: The smartness status of the hospitals was found to be moderate, with 71% of hospitals falling into this category. A significant correlation was observed between the smartness of hospital units, the type of hospital (teaching or non-teaching), and the hospital's specialization (specialized or general) ($P = 0.013$). Significant and direct correlations were also found between information technology and hospital units ($P = 0.043$), management systems and clinical processes ($P = 0.008$), and overall smartness and clinical processes ($P = 0.049$).

Conclusions: Public hospitals need improvements in smartness indicators. Factors such as whether the hospital is teaching or non-teaching and whether it is specialized or general should be taken into account. Moreover, hospital smartification efforts should adopt a comprehensive approach, considering all dimensions of smartness.

Keywords: Hospital, Smartness Status, Hospital Characteristics, Hospital Performance Indicators

1. Background

Information technology, digital transformation, and innovation in artificial intelligence can contribute significantly to optimizing healthcare management systems (1). Given the emphasis placed by various countries on the importance of technology and its impact on delivering quality healthcare services, hospitals, as the primary providers of medical services, require special attention to information technology (2). One of the most significant manifestations of information technology development is the smartification of organizations, which involves utilizing cutting-edge technologies such as the Internet of Things, big data, cloud computing, and artificial intelligence. These technologies enable easier, more efficient, and personalized healthcare delivery, creating comprehensive transformations in medical systems (3).

Hospitals, as crucial healthcare providers, play a vital role in improving public health (4, 5). A portion of hospitals' operational success relies on implementing technologies (6) and utilizing smart equipment and processes (7). A smart hospital is typically associated with a comprehensive care model that aims to meet stakeholders' economic, operational, and

environmental needs while improving the quality of care and promoting sustainable utilization (8). Using cutting-edge technologies in smart hospitals helps solve various healthcare challenges, such as early diagnosis, quality of care, remote care, and cost-effective treatments (9-11).

The smartification of hospitals offers several advantages, including cost savings, increased speed, accuracy, and reliability, improved safety and patient comfort, enhanced patient and staff satisfaction, and better equipment tracking and security (10, 12). Smart hospitals can also control temperature, humidity, and air quality and assist in managing personnel, patients, and equipment within an integrated system (13, 14). Evidence suggests that using smart networks has improved hospital efficiency, resulting in a 42% reduction in costs, an 87% saving in patient service time (15), and a 20% reduction in energy consumption (10). Additionally, these centers can help mitigate shortages in the medical workforce. In Japan, for example, smart hospitals have been designed to address physician shortages (16).

The smartification of hospitals is still in its early stages. Given the benefits and necessity of smartification, studies that assess the current status of hospital smartness and identify gaps are essential. Such research can strengthen the information and technical infrastructure needed to develop smart hospitals and guide policy-making in healthcare (17). Studying the smartness status of existing hospitals and measuring relevant metrics can influence healthcare policies and create new approaches to hospital administration (7). Despite the increasing importance of hospital smartification, there is a lack of information and assessment tools due to its novelty, resulting in only a few studies conducted in this field (18).

In Iran, 70% of hospital beds are in public hospitals (19). These facilities provide services to the population at government-regulated rates, which are the lowest tariffs available nationwide (20). In some underprivileged regions, these public hospitals serve as the only accessible healthcare facilities for residents (21). This situation poses greater challenges in deprived cities with lower hospital bed ratios (22). Public hospitals are typically located in busy, central areas (23) and are expected to accommodate high patient visits and diverse needs (24). These conditions, along with the benefits of smartification, emphasize the need for a focus on the intelligent performance of public hospitals (24, 25)

When analyzing a specific situation within an organization, it is essential to consider its primary characteristics and evaluate their interrelationships (26). In the context of hospitals, characteristics such as duration of existence (27), teaching/non-teaching status (28), and specialization (general or specialized services) (29) are emphasized. Additionally, performance indicators such as bed occupancy rate (30), patient admission volume (31), average length of stay (32), and mortality rate (33) should be evaluated, as they are relevant to hospital smartification. Therefore, this study focuses on three domains smartification, core characteristics, and performance indicators and their interrelationships within public hospitals.

2. Objectives

The study aimed to evaluate the smartness status of public hospitals and examine its correlation with hospital characteristics and performance indicators. Identifying the current status, gaps, and influential factors in hospital smartness is crucial for guiding future improvements.

3. Methods

3.1. Study Design

This cross-sectional descriptive-analytical study was conducted in seven public hospitals in Alborz Province, Iran, during 2023 - 2024. The hospitals were randomly selected from 12 hospitals affiliated with Alborz University of Medical Sciences.

3.2. Data Collection

The researcher visited the hospitals to collect relevant characteristics and performance indicators. Data were gathered using two instruments: A researcher-designed questionnaire consisting of seven questions, including three related to hospital characteristics: (1) duration of hospital existence, (2) type of hospital (teaching or non-teaching), and (3) specialization (specialized or general), and four related to performance indicators: (1) bed occupancy rate for the previous year, (2) average length of patient stay for the previous year, (3) number of hospital admissions for the previous year, and (4) number of patient deaths for the previous year). These questions were included based on a review of the literature and expert opinions. The questions regarding hospital characteristics were designed based on their potential impact on smartification, while the questions about performance indicators were designed based on their potential susceptibility to smartification.

Table 1. Characteristics of Experts for Validating the Questionnaire Questions (Hospital Characteristics and Performance Indicators)

Expertises	Experience
Ph.D. in healthcare services management	Hospital management
Ph.D. in health economics	Management in Healthcare Economics
Ph.D. in health information technology	Hospital statistics analyst
Ph.D. in biostatistics	Hospital statistics analyst
Ph.D. in healthcare services management	Hospital management, hospital quality improvement
Cardiologist	Hospital director
Ph.D. in health policy	Hospital Establishment and Development Consultant
Ph.D. in information technology	Active in Artificial Intelligence and Intelligent Systems

The questionnaire's content validity was confirmed by study experts. A focus group discussion (FGD) was held with a panel of eight experts with relevant expertise and experience. Through consensus, they confirmed the validity of the questions (Table 1).

The "Smart Hospital Assessment Checklist" was utilized to assess the smartness status of each hospital. The researcher completed the checklist by observing the physical space, facilities, and equipment, reviewing documents, and interviewing various unit officials. The checklist consists of eight main domains and 138 metrics. The relevant domains include the hospital building (32 metrics), hospital units (37 metrics), safety processes (17 metrics), clinical processes (6 metrics), management systems (6 metrics), patient processes (4 metrics), green management (21 metrics), and information technology (15 metrics). Each indicator is rated on a scale of "present," "in progress," or "absent," with corresponding scores of 2, 1, and 0, respectively. The content validity of the tool was confirmed through acceptable scores for the Content Validity Ratio (CVR > 0.51) and Content Validity Index (CVI > 0.79), as well as formal criterion validity and predictive criterion validity. The tool's reliability was assessed using Cronbach's alpha coefficient (α = 0.82) by Hosseini et al. (18).

3.3. Data Analysis

The total scores for each domain and the overall checklist score were calculated for each hospital to determine the overall smartness status and related domains. Based on the predetermined quartiles shown in Box 1, hospitals' smartness status and their respective domains were determined. Descriptive statistics and statistical analyses, including independent *t*-tests, Pearson's correlation, Spearman's correlation, and analysis of variance (ANOVA), were performed using SPSS version 24 software to report the findings and analyze the data.

Box 1. Quartile Classification of Scores for Overall Smartness Status and Related Domains

Variables
Overall smartness status
207 > weak ≥ 138
276 > moderate ≥ 207
345 > Good ≥ 276
414 ≥ Excellent ≥ 345
Hospital building
48 > weak ≥ 32
64 > moderate ≥ 48
80 > Good ≥ 64
96 ≥ Excellent ≥ 80
Hospital units
55.5 > weak ≥ 37
74 > moderate ≥ 55.5
92.5 > Good ≥ 74
111 ≥ Excellent ≥ 92.5
Safety processes
25.5 > weak ≥ 17
34 > moderate ≥ 25.5
42.5 > Good ≥ 34
51 ≥ Excellent ≥ 42.5
Clinical processes
9 > weak ≥ 6
12 > moderate ≥ 9
15 > Good ≥ 12
18 ≥ Excellent ≥ 15
Management systems
9 > weak ≥ 6
12 > moderate ≥ 9
15 > Good ≥ 12
18 ≥ Excellent ≥ 15
Patient processes
6 > weak ≥ 4
8 > moderate ≥ 6
10 > Good ≥ 8
12 ≥ Excellent ≥ 10
Green management
31.5 > weak ≥ 21
42 > moderate ≥ 31.5
52.5 > Good ≥ 42
63 ≥ Excellent ≥ 52.5
Information technology
22.5 > weak ≥ 15
30 > moderate ≥ 22.5
37.5 > Good ≥ 30
45 ≥ Excellent ≥ 37.5

4. Results

Among the seven hospitals, three were teaching hospitals, with a bed occupancy rate of over 60%. The remaining four were general hospitals, which had a shorter history compared to the teaching hospitals.

Table 2. Hospitals' Characteristics and Performance Indicators

Hospital Code	Hospitals' Characteristics			Hospitals' Performance Indicators			
	Duration of Hospital's Existence(y)	Type of Hospital (Teaching or Non-teaching)	Specialization Orientation (Specialized or General)	Bed Occupancy Percentage (2022)	Average Length of Patient Stay (2022)	Number of Hospital Admissions (2022)	Number of Patient Deaths (2022)
1	59	Teaching	Trauma	88%	3.7	24621	379
2	41	Teaching	Heart	80%	4.2	15641	795
3	72	Teaching	Women	65%	2.6	26103	85
4	8	Non-teaching	General	63%	3	11360	322
5	12	Non-teaching	General	26%	4.2	1145	23
6	30	Non-teaching	General	15%	1.9	676	0
7	29	Non-teaching	General	39%	3.9	2487	98

Table 2 displays the hospitals' characteristics and performance indicators separately.

The smartness scores for each hospital were calculated. One hospital's smartness status was rated as weak, five hospitals were rated as moderate, and only one hospital was rated as good. Additionally, among the smartness domains, only the clinical processes, management systems, and green management domains were assessed as good, while the other domains were rated as moderate (Table 3).

In the subsequent analysis, no significant correlation was found between the average scores of overall smartness and the relevant domains with the duration of the hospital's existence, bed occupancy rate, average patient stay, number of hospitalized patients, or number of deaths. However, a significant correlation was observed between the average score of the hospital units domain and the type of hospital (teaching or non-teaching) and specialization orientation (specialized or general hospitals) (P-value = 0.013). Additionally, significant differences were found in the average scores of safety processes (P-value = 0.029) and green management (P-value = 0.041) among the seven hospitals. Furthermore, significant and positive correlations were observed between information technology and hospital units (P-value = 0.043), management systems and clinical processes (P-value = 0.008), and overall smartness and clinical processes (P-value = 0.049) (Table 4).

5. Discussion

The overall smartness status of the hospitals was moderate. None of the seven hospitals exhibited an excellent smartness status. Two hospitals had a moderate status, and one had a good status. However, none of the non-teaching hospitals showed good status, with three having a moderate status and one having a weak status. Despite the progress of hospitals in developed countries towards smartification and their favorable status in this technology, a complete understanding of the value of investments in smart technologies has not yet been achieved (16), and this approach is still in its early stages. It is expected that with the rapid growth of this technology and the increasing needs of the studied hospitals, the observed statuses in the findings will improve over time.

Among the examined smartness statuses, no excellent or poor statuses were observed. The domains of clinical processes, management systems, and green management were in a good status, while hospital building, hospital units, safety processes, patient processes, and information technology were in a moderate status. In line with Rasoulian Kasrineh et al. (34), effective and efficient resource management has been emphasized across various domains in this study. Additionally, a study using similar smartness metrics indicated that the Mayo Clinic and Johns Hopkins Hospital ranked at the top level of smartness (35).

In the smartness of hospital buildings, no excellent status was observed. The overall status of teaching hospitals was better than that of non-teaching hospitals. In infrastructure development, smartification can lead to long-term cost savings and reductions in maintenance costs, making investment in smartification economically justifiable (11). The design of hospital buildings, as the main framework for implementing smart hospitals, should be compatible with appropriate smart technologies and equipment (36) and aligned with the infrastructure and functions of urban communities (37).

The smartness of hospital units, which include various clinical, paraclinical, administrative, and support departments, was moderate. On average, teaching and specialized hospitals had better smartness statuses than general non-teaching hospitals. Considering the significant statistical relationship

Table 3. Smartness Status of Studied Hospitals by Relevant Domains

Domains Hospital	Hospital Building	Hospital Units	Safety Processes	Clinical Processes	Management Systems	Patient Processes	Green Management	Information Technology	Overall Smartness Status
1	49 (Moderate)	76 (Good)	29 (Moderate)	12 (Good)	12 (Good)	9 (Good)	29 (Weak)	21 (Weak)	239 (Moderate)
2	47 (Weak)	67 (Moderate)	37 (Good)	9 (Moderate)	6 (Weak)	5 (Weak)	48 (Good)	28 (Moderate)	247 (Moderate)
3	66 (Good)	64 (Moderate)	47 (Excellent)	12 (Good)	17 (Excellent)	4 (Weak)	48 (Good)	19 (Weak)	277 (Good)
4	39 (Weak)	84 (Good)	38 (Good)	15 (Excellent)	15 (Excellent)	7 (Moderate)	47 (Good)	26 (Moderate)	271 (Moderate)
5	37 (Weak)	53 (Weak)	32 (Moderate)	15 (Excellent)	15 (Excellent)	11 (Excellent)	38 (Moderate)	19 (Weak)	220 (Moderate)
6	54 (Moderate)	40 (Weak)	21 (Weak)	9 (Moderate)	9 (Moderate)	4 (Weak)	38 (Moderate)	26 (Weak)	201 (Weak)
7	59 (Moderate)	78 (Good)	27 (Moderate)	11 (Moderate)	15 (Excellent)	7 (Moderate)	45 (Good)	19 (Weak)	261 (Moderate)
Average	50 (Moderate)	66 (Moderate)	33 (Moderate)	12 (Good)	13 (Good)	7 (Moderate)	42 (Good)	23 (Moderate)	245 (Moderate)

between hospital units, type of hospital (teaching or non-teaching), and specialization (specialized or general), it is evident that the addition of educational responsibilities and the presence of professors, mentors, and students in various units, along with the need for innovative educational interventions (38), resulted in better smartness statuses in teaching hospitals. Additionally, specialized hospitals often deploy more specific equipment and demonstrate more precise performance in their areas of specialty (39), which increases their potential for smartification.

A significant and direct statistical relationship was also observed between the smartness of hospital units and information technology smartness. Since one of the primary pillars of hospital smartification is related to information technology, the development of IT in hospitals extends to various hospital units, ultimately increasing the level of smartness in those units (40). Conversely, as the smartification of units progresses, their equipment and technologies also become smarter.

Patient safety is a vital and sensitive aspect of hospital smartification. The use of artificial intelligence in hospitals can enhance patient safety (41). The study findings indicate that the smartness status of teaching hospitals is better than that of non-teaching hospitals. Kakemam et al. (42) also revealed that attention to patient safety in Iranian teaching hospitals is good. Additionally, a significant difference was found in the average scores of safety processes among the seven hospitals. The smartness of patient safety processes may differ among hospitals due to various leadership styles and management perspectives (43). Smartness in patient safety requires a unified, integrated approach and should be free from personal biases to ensure compliance with different characteristics and management approaches (44).

The smartness status of clinical processes was good overall. Two non-teaching hospitals achieved excellent status, two teaching hospitals were rated as good, and the remaining centers had moderate statuses. The findings showed a significant and direct relationship between the smartness of clinical processes and the overall smartness status of the hospitals. Therefore, the smartness of clinical processes, as the primary and most sensitive provider of hospital services (45), plays a key role in the overall smartness of the institution. Additionally, a significant relationship was observed between the smartness of clinical processes and management systems. Since smart management positively impacts organizational performance (46), it is expected that as the smartness of management systems improves, so too will the smartness of clinical processes in hospitals.

Smartification can increase efficiency and reduce the time spent on managerial support services (47). According to the findings, the highest level of smartness was observed in management systems, with four hospitals being rated as excellent. One reason for this is the availability of monitoring tools and the overall development of information technology, along with indirect supervision by the Ministry of Health and Medical Education (MoHME) and centralized oversight by the University of Medical Sciences on hospitals and managers' performance (48). A smartification approach and the commitment of hospital management are crucial for increasing smartness. Hospital managers should strive to equip their organizations with smart hospital components and align all processes and equipment with transformative technologies (14).

Table 4. Correlation Between Scores of Overall Smartness and Relevant Domains in the Studied Hospitals [a, b]

Hospital, Domains and Correlations	Hospitals	Hospital Building	Hospital Units	Safety Processes	Clinical Processes	Management Systems	Patient Processes	Green Management	Information Technology	Overall Smartness Status
Hospital building										
Correlation	0.086	1	-0.046	0.388	-0.490	-0.160	-0.595	0.151	-0.168	-0.015
P-value	0.855		0.922	0.390	0.264	0.732	0.159	0.747	0.718	0.975
Hospital units										
Correlation	0.085	-0.046	1	0.147	0.383	0.381	0.185	0.234	0.769 [a]	0.703
P-value	0.855	0.922		0.754	0.397	0.399	0.691	0.614	0.043	0.078
Safety processes										
Correlation	0.805 [a]	0.388	0.147	1	0.137	0.000	-0.361	0.412	-0.094	0.557
P-value	0.029	0.390	0.754		0.770	10.000	0.426	0.359	0.842	0.194
Clinical processes										
Correlation	0.094	-0.490	0.383	0.137	1	0.884 [b]	0.640	-0.124	0.000	0.757 [a]
P-value	0.840	0.264	0.397	0.770		0.008	0.122	0.791	10.000	0.049
Management systems										
Correlation	-0.134	-0.160	0.381	0.000	0.884 [b]	1	0.528	-0.176	-0.061	0.696
P-value	0.775	0.732	0.399	10.000	0.008		0.224	0.706	0.897	0.083
Patient processes										
Correlation	-0.403	-0.595	0.185	-0.361	0.640	0.528	1	-0.635	0.037	0.301
P-value	0.370	0.159	0.691	0.426	0.122	0.224		0.125	0.938	0.512
Green management										
Correlation	0.774 [a]	0.151	0.234	0.412	-0.124	-0.176	-0.635	1	0.500	0.236
P-value	0.041	0.747	0.614	0.359	0.791	0.706	0.125		0.253	0.610
Information technology										
Correlation	0.194	-0.168	0.769 [a]	-0.094	0.000	-0.061	0.037	0.500	1	0.328
P-value	0.086	1	-0.046	0.388	-0.490	-0.160	-0.595	0.151	-0.168	-0.015

[a] Correlation is significant at the 0.05 level (2-tailed).

[b] Correlation is significant at the 0.01 level (2-tailed).

Continuous monitoring by managers is also necessary to ensure goal achievement at all levels (49).

The smartness status of patient processes was moderate, and most hospitals (five cases) were in a weak status. It appears that patient process smartness has not received sufficient attention in hospitals. Ryu et al. emphasize the importance of patient-centered smart services (50). Patients are value-creating customers for the hospital organization, and efforts to make processes related to them smarter will positively impact their satisfaction (51) and ultimately contribute to the hospital's success in achieving its organizational goals (52).

The smartness of green management in hospitals was rated as good or moderate, with the average status being moderate. Smart performance in this domain can promote environmental sustainability and contribute to the hospital's sustainable development (53). Optimal energy management is also emphasized, as it can lead to cost reductions for the hospital (54). The findings revealed a significant difference in the average scores of smartness in green management among the seven hospitals, reflecting different approaches and performances. This indicates a lack of a unified, centralized approach to green management.

Hospitals' smartification is achievable through innovative information technologies, and success in utilizing and implementing IT can positively impact the smartness of other sectors (1). However, the overall status of hospitals in this domain was moderate or weak, which is not desirable. Smart hospitals can optimize care and reduce costs through digital communication technologies such as video conferencing, SMS, remote monitoring, and telehealth. The Internet of Things is also a critical component of the IT domain, and its use in various healthcare stages can

reduce errors. However, considering its effectiveness varies across diseases (2), its use should be approached with caution.

Given the importance of smartification and the growing need for technology, we recommend that hospitals develop short-term, medium-term, and long-term plans for smartification. Since there is no national obligation, hospitals should voluntarily take steps towards smartification. Additionally, we suggest that the smartness status of hospitals be included as a separate category in national accreditation evaluations conducted by the MoHME. Including smartness status evaluations in internal evaluations conducted by Medical Universities' Deputies could also be beneficial. Public incentives and active industry participation are necessary to strengthen and facilitate the smartification of hospitals (7).

We recommend that medical universities and hospitals implement smart systems in their management departments to kick-start smartification. This can help managers understand the importance and utility of smartification and act as a driving force for overall hospital smartification. Considering the significant differences in performance among hospitals in safety and green management, we suggest that a comprehensive action plan and monitoring program be developed by the MoHME and Medical Universities. This plan should incorporate the experiences of successful universities and hospitals and aim for the integrated implementation of smartness metrics in these domains.

5.1. Limitations

Given the novelty of the smart hospital concept and the limited number of relevant studies, achieving a comprehensive comparison among the relevant domains was not possible, which is one of the limitations of this study. Additionally, the lack of familiarity of hospital managers and staff with the study and some of the metrics necessitated separate explanations for them.

5.2. Conclusions

Considering that the smartification of hospitals, especially in developing countries like Iran, is in its early stages, it is not surprising to observe unsatisfactory conditions in overall status and related domains, particularly in public hospitals that face numerous challenges. The observed statistically significant correlation between two hospital characteristics and one of the smartness domains supports the hypothesis that a hospital's general attributes are associated with its level of technological sophistication. This finding warrants further investigation to elucidate the relationship between hospital characteristics and various dimensions of smartness. Additionally, the lack of correlation between performance indicators and smartness status can form the basis for further research. The interplay between the overall smartness score and other factors highlights the need for attention to all dimensions of smartification and a cohesive approach to its implementation. Given the challenges faced by public hospitals, smartification is likely to assist in mitigating these issues, and therefore, it is advisable to prioritize smartification and expedite the implementation of all its domains in hospital agendas.

Footnotes

Authors' Contribution: S. H. H. conceived the study; Y. P. contributed to data collection and drafting the manuscript; S. H. H. contributed to the analysis, drafting, editing, and revision of the manuscript; M. A. contributed to the revision of the manuscript. All authors read and approved the final manuscript.

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