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Predicting the number of IT staff needed in hospitals of Isfahan University of Medical Sciences based on modeling in 2023: A descriptive-analytical study

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Abstract

Background and Aims: Considering the increasing use of information technology (IT) and the need of the implementation of related projects, the lack of IT specialists in the health system is one of the major challenges that require planning and foreseeing. This study was conducted with the aim of predicting the number of required IT personnel in hospitals of Isfahan University of Medical Sciences based on the modeling of identified and weighed influential factors in 2023.

Method: First, Delphi method and multi-criteria decision-making (MCDM) using the Expository Posthaste Effective Resemblant Tool (ExPERT) were conducted to identify and weigh the components that affect IT staff's workload in hospitals. Then, the model for predicting the required number of IT personnel for the involved hospitals was developed. In all stages, the obtained information and results were checked and confirmed using experts' opinions in Focus Group Discussions.

Results: Twenty-one hospitals (57%) out of 37 hospitals are facing a shortage of IT personnel. This varies from 0.5 to 1.6 personnel in different hospitals. Thirteen hospitals (35%) were reported to have adequate IT staffing and three hospitals (8%) had excess IT staffing.

Conclusion: This study provided a predictive model for required IT staff in hospitals using MCDM through ExPERT which can be used in cases where the use of workload-based methods such as Workload Indicators of Staffing Need is complex or time-consuming.

KEYWORDS
hospital, human resources, IT staff, modeling, multi-criteria decision making

1 | INTRODUCTION

Manpower is considered the most basic part of healthcare.[1] The proper recruitment and use of human resources in terms of number and composition can guarantee the quantity and quality of hospital services and prevent unnecessary costs.[2] To meet the health needs of the population, the use of workforce planning methods can help the analysis and decision-making process to allocate the right number of specialists in the right place and at the right time.[3] In other words, human resource planning in the health sector includes determining the number, composition, and distribution of the human resources that will be needed to meet the health needs of the population in the future.[4] Hospitals, as service organizations that play a key role in the health system, can't do without human resource planning.[5] The problem of imbalance and lack of sufficient human resources in these centers causes unfavorable performance in providing services.[1]

To provide efficient and effective health services, the existence of sufficient staff in all occupations of health care is inevitable. In many countries, much of the effort has focused on the "traditional" occupations of health staff (e.g., doctors and nurses) and neglected the other occupations that are necessary to provide quality health care and other determinants of health.[6] Since the dependence of organizations on information technology (IT) is increasing and integrated information systems are becoming more popular every day, IT is an important success factor in organizations. As it increases productivity and provides many opportunities to gain competitive advantages including operational efficiency, cost savings, and reduction of human mistakes. Therefore, the lack of human resource specialists in IT is one of the challenges of human resource management in educational and medical centers. So, in solving this problem, planning and foreseeing should be one of the priorities.[7]

There is a scarcity of studies estimating the IT staffing needs in this field,[8] with existing research primarily focusing on health information technology (HIT) staffing. However, it's worth noting that only a portion of the duties performed by these personnel are strictly IT-related.[9] In 2008, Hersh and Wright[10] delved into the workforce requirements for HIT in the United States. Their study analyzed the size, growth, and characteristics of this workforce using data from the Healthcare Information Management Systems database, which included metrics such as the number of beds, staff count, and the eight-step model of electronic record adoption (EMR). The study's findings revealed a HIT-to-total staff ratio of 60.7. Through a weighted average method, they estimated that by 2014, an additional 40,784 HIT professionals would be necessary to propel the entire United States to higher levels of EMR adoption.[10] In 2018, the same study was revisited, uncovering that due to the rapid growth of EMR levels in hospitals, the previous estimate fell short by 8% of the actual growth of the HIT workforce.[8] Furthermore, Hersh et al.,[8] in a comprehensive review study, examined 11 studies on the HIT workforce, revealing that only three of them attempted to quantify the number of HIT personnel across the entire healthcare system. According to their report, England's National Health Service (NHS) estimated a need for one HIT employee for every 52 non-HIT employees, encompassing all roles involved in information systems within the NHS. Similarly, an Australian study estimated one HIT professional for every 50 non-HIT workers in the health system. Other studies reviewed focused on describing job roles rather than quantifying them.[9]

In Iran's hospitals and other healthcare sectors, the roles of IT specialists and HIT specialists differ significantly, leading to distinct requirements for manpower planning in these fields. A study conducted in Kashan in 2016 revealed that, despite the commendable IT proficiency among HIT personnel, their current job roles underutilize these skills.[11] As per the task descriptions outlined by the Ministry of Health and Education of Iran, IT experts, including those in hospital settings, are tasked with a variety of responsibilities across different domains. These include overseeing the procurement, management, and maintenance of technical equipment (hardware domain), managing network infrastructure and troubleshooting connectivity issues (network domain), maintaining operating systems, and databases, and providing system support (software domain), as well as administering internal portals and implementing security measures (security and portal domain).[12] Moreover, within university-affiliated hospitals, systems are implemented collaboratively and seamlessly integrated, ensuring uniform levels of electronic services and IT across all facilities. Consequently, allocating an adequate number of IT personnel to each hospital requires consideration of additional influential factors, such as hospital size and available facilities. In Iran, some studies have evaluated the human resources status of various hospital departments, focusing primarily on specialized health personnel. However, in the best-case scenario, only one "administrative" group, encompassing employees from all administrative departments, has been considered. For instance, Niazi and Jahani's study in hospitals covered by Babol University of Medical Sciences and Ghaem Shahr Social Security revealed a surplus of staff in administrative and financial departments, coupled with a lack of staff in medical and paraclinical departments.[1] Similarly, Shafiei et al. investigated the human resources situation in two hospitals in Yazd City, highlighting a surplus of 36 and 29 people in the administrative units of the respective hospitals.[5] Therefore, based on the investigations conducted thus far, no study has specifically estimated the IT staff of hospitals in Iran or other countries. This gap in research poses challenges to the field, particularly concerning policies aimed at promoting Electronic Health Records to enhance healthcare quality and efficiency. Without a sufficiently large and well-trained IT workforce, such initiatives are at risk of failure.[8]

Many human resources studies in the healthcare sector, particularly those concerning the HIT workforce, have traditionally relied on descriptive methods using simple ratios based on factors like bed count or population density, which no longer adequately address the complexity of population health needs or emergency situations. Health policy planners must now be equipped to make informed decisions regarding the recruitment and deployment of health workers across primary, secondary, and tertiary healthcare facilities, aligning with evolving models of healthcare delivery and population demands.[6,8] Since 2010, the Workload Indicators of Staffing Need (WISN) method has become widely adopted for estimating workforce requirements across various healthcare sectors.[13] While the WISN method offers numerous benefits and is extensively used in human resources research, its implementation in estimating Isfahan hospital's IT workforce requirements is hindered by several factors. The successful use of the WISN method in force estimation is conditional on the availability of quality and valid data on the activities performed and when they are performed.[14] One primary challenge is the lack of officially or unofficially recorded statistics on the activities of IT experts in university-affiliated units, including hospitals. Collecting reliable and up-to-date information in this regard is time-consuming. Furthermore, due to staffing shortages in other departments and the versatile skillsets of IT personnel in many hospitals, these professionals are often reassigned to other units. Additionally, inadequate facilities in some organizations result in reduced workloads, leading to lower recording statistics than expected. Consequently, utilizing the WISN method may underestimate the required manpower compared to the actual need.[15]

Therefore, making informed decisions regarding the required human resources in IT for hospitals is essential yet complex. Currently, there is no universally accepted or accurate model for determining IT staff in hospitals. Additionally, the multifaceted nature of their roles complicates decision-making in this field. Technical factors such as infrastructure, software, hardware, and security, along with various healthcare and hospital-specific factors like age, the extent, and type of hospital, can significantly influence staffing needs. Hence, it is crucial to identify the influencing factors in determining the required number of IT personnel for hospitals and weigh their importance accordingly. Researchers are turning to multi-criteria decision-making methods (MCDMs) to address these challenges, as they enable simultaneous consideration of multiple decision-making factors and determination of their relative importance.[16] However, the literature review suggests that MCDM methods have not been extensively applied in this field. Nevertheless, due to the complexity involved in implementing MCDM, selecting an efficient and appropriate method is paramount.[17] To address this, the current research employs a combination of the Delphi method, MCDM, and focused discussions to achieve three key objectives:

1. Identifying the components that determine the workload of IT staff in hospitals.
2. Determining the importance and weighting of these identified components.
3. Modeling and estimating the required staff for each hospital, thereby providing an overview of the current IT workforce situation within this university's hospitals in terms of shortages or surpluses based on the developed model.

2 | METHODS

This descriptive-analytical study was conducted to predict the number of required IT personnel in the hospitals of Isfahan University of Medical Sciences based on the modeling of the influential factors identified and weighed in 2023. To do this, we aim to first identify the components that determine the workload of information technology employees in hospitals, including various infrastructural, software, hardware, and environmental aspects, using the Delphi method. In the second stage, we examine the influence of each factor and the importance of these factors in determining the required IT workforce using the MCDM method and the Expository Posthaste Effective Resemblant Tool (ExPERT). Finally, by combining the identified effective factors and their relative weights, we present a mathematical model for estimating the final IT workforce required by hospitals. In all phases, the obtained information and results were examined and verified through experts' opinions and Focus Group Discussions.[18] The study was conducted in the following three main phases:

2.1 | Identifying factors affecting the workload of IT staff in hospitals

The Delphi method was used to identify factors affecting the workload of IT staff.[19,20] Initially, a meeting was convened at the university's IT management office, attended by the university's software, hardware, and infrastructure managers. From a pool consisting of 74 hospital IT personnel and 40 university management IT specialists, 10 experts who met the entry criteria were carefully selected to form the Delphi panel. The entry criteria for the Delphi panel included having sufficient knowledge in the field of IT, possessing at least 5 years of work experience in the field, demonstrating diversity in activity levels (e.g., university headquarters, single specialty hospital, and general hospital), and exhibiting diversity in service areas (e.g., Isfahan city and other cities). IT expert participation was voluntary. Information on the study purpose, process, and outputs was provided to the panelists through a phone call. Verbal Informed consent was obtained from all panelists before their participation in this Delphi panel.

Subsequently, each member of the group underwent a separate and confidential interview. The key question posed was: "In your opinion, what factors are effective and should be taken into account to determine the number of IT personnel required by hospitals?" Following this initial question, each expert was allotted 1 day to contemplate these factors. Subsequently, based on the expert's initial response, the interview continued, and all perspectives were meticulously recorded

The results of the interviews and the identified influential factors were summarized by the researchers and discussed in focus group meetings. Subsequently, duplicate, unrelated, or uncollectible factors were removed, and common factors were merged to create a basic Delphi checklist comprising 13 items. This checklist utilized a 10-point scale ranging from unimportant to very important for scoring. Additionally, experts were invited to indicate if they had any other viewpoints beyond the 13 identified items. In the first round of the Delphi process, factors receiving a score higher than 7 or lower than 3 by at least 70% of the experts were approved or disapproved, respectively.[20] Factors without sufficient agreement underwent rescoring in the second round. From the initial 13 items, 9 were confirmed, while 4 lacked agreement. The experts' additional viewpoints did not lead to the addition of new items. In the second round, experts reconsidered the remaining four items, resulting in the confirmation of one item and the removal of the other three. Through these two rounds of Delphi, a final list of 10 influencing factors was created. It's worth noting that following data collection, the correlation between identified factors was examined. Two items exhibited a strong and significant correlation, leading to the retention of only one in the study.

2.2 | Weighing factors and designing a predicting model for the number of IT staff required by hospitals

After identifying and confirming the influential factors using the Delphi method, the selected factors were weighed. The weight of each factor shows its importance and value compared to other factors. The factors were weighed in 2 phases:

2.2.1 | Internal weighting

In the first phase, in the Focus Group Discussion, each factor was classified by considering the impact of its changes on the workload of the IT personnel of the hospitals. Then, the classes of each factor were valued compared to each other.[16] For example, one of the most significant influencing factors identified was the number of computers and their accessories in each hospital. According to experts, the workload of IT personnel varies significantly based on this factor. For instance, in the initial classes, every 75 computers, and in subsequent classes, every additional 150 computers, markedly impacts the workload. Therefore, considering the range of computers in the studied hospitals (from 35 to 1175 computers), this factor was divided into nine classes, each assigned an approximate weight of 0.11 (w_i). These results were utilized to prepare the ExPERT for identifying weights in the next stage.)

2.2.2 | External weighting

In the second step, the relative importance of the set of identified factors (external weighting) was determined using the MCDM method. In this approach, the factors identified in the previous step were considered as decision criteria. While common methods such as the Analytic Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment of Evaluation (PROMOTHEE) are typically used for MCDM,[16] their application in this research posed challenges due to a large number of factors (nine in total). The pairwise comparison process in these methods could be difficult, exhaustive, and time-consuming, potentially leading to increased user error in assigning weights.[17] Therefore, the visual tool ExPERT was employed in this study to implement the MCDM method. Unlike traditional methods, ExPERT offers the advantages of AHP and PROMOTHEE while providing visual comparison and simplifying the process of adjusting factor weights.[17]

FIGURE 1 Bar chart for weighting of factors.

For this purpose, the identified factors, along with the classes and weights obtained from the previous stage, were input into the ExPERT tool to facilitate MCDM. The tool was then provided to a group of experts in the form of a link, enabling them to determine the relative factors (external weighting). The experts received the necessary training to utilize this tool and were requested to record their responses within a week.

When using this tool, decision makers can simultaneously view all factors in the form of a bar graph and record their perceived level of importance (on a scale of 0–100) graphically and visually (Figure 1). Additionally, the tool includes an embedded pie chart, which dynamically reflects the contribution or relative importance of each variable compared to others (Figure 2). Furthermore, textual descriptions of expert scores are provided beneath these charts, allowing experts to review explanations of their weights (Figure 3). Finally, initial approval is required from the experts before proceeding to the next step.[17]

After recording the weights by the experts, the second stage involves displaying basic information related to the factors of several hospitals and their scores based on the assigned weights to the user. During this stage, experts can review the feedback of their weighting in calculating the final scores across several hospitals and adjust the weights of the factors by returning to the previous stage if necessary (Figure 4). Finally, the ExPERT tool requests final approval to finalize the weighting process. Each expert independently weights the factors using this tool, and upon final user confirmation, the assigned weights are sent to the server. Subsequently, by averaging the final weights recorded by different experts, the final weight of each factor (α_i) is determined.[17]

Finally, akin to other MCDM methodologies, each hospital was assigned a final score based on the weighted factors. To achieve this, after determining the weights of the inner classes of each variable (w_i) and the relative importance of the variables to each other (α_i) in the preceding steps, the subsequent formula was utilized to amalgamate the results and compute the score for each hospital:

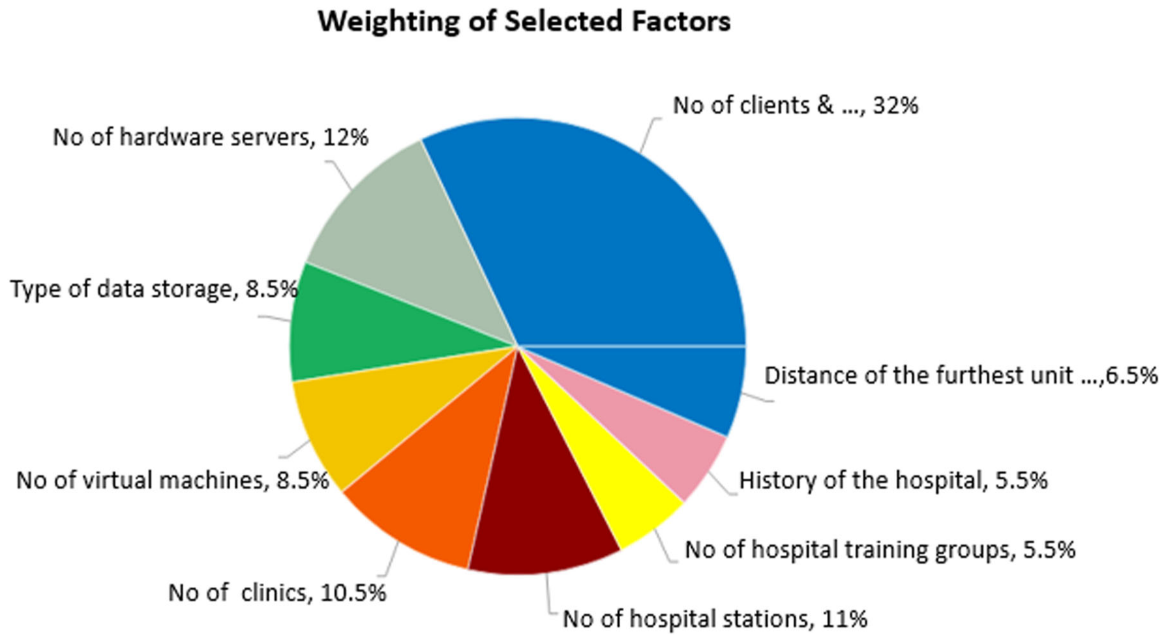

FIGURE 2 Pie chart of importance of factors.

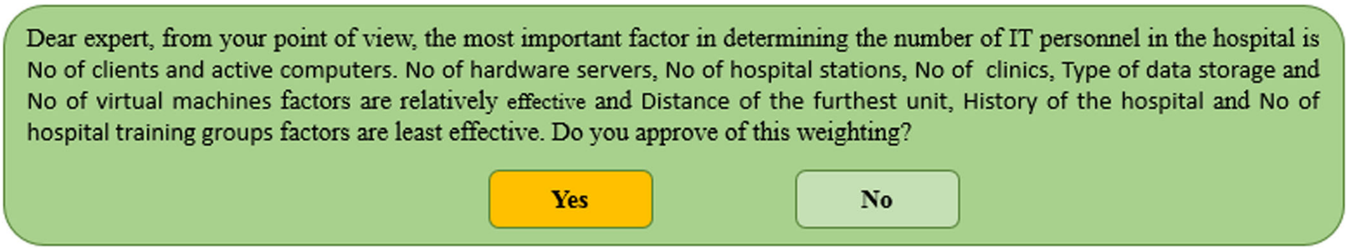

FIGURE 3 Textual descriptions of expert scores. IT, information technology.

$$\text{the score of the } j\text{th hospital} = \sum_{i=1}^{9} \alpha_i \omega_{ij},$$

where α_i = the external weight of the ith factor (average coefficients assigned by experts) and ω_{ij} = the internal weight of the ith factor in the jth hospital

2.3 | Evaluation of the model

The results of the previous phase led to the prioritization of hospitals based on their required IT staff, where the hospital scoring the highest needed the most staff, and vice versa.[17] These results underwent review during two focus group sessions with experts for evaluation and verification. In the first session, contradictions emerged in the results and the initial prioritization of model implementation. Consequently, the initial hospital information was reviewed and corrected, prompting a repetition of the second step using the corrected data. Additionally, based on the opinion of research statistical experts, modifications to the mathematical model were suggested as follows:

$$\text{the score of the } j\text{th hospital} = \sum_{i=1}^{9} \alpha_i \frac{\omega_{ij}}{\min \omega_i},$$

where α_i and ω_{ij} remain as previously mentioned, with $\min \omega_i$ representing the minimum internal weight of the ith factor.

It should be noted that due to the varying number of classes for each item and the independent internal weighting of each item, the coefficient $\frac{1}{\min \omega_i}$ was included in the linear combination. While the addition of this coefficient did not significantly alter the study results, it standardized the internal weights of the items and made them comparable to each other. Furthermore, it underscored the real importance of the classes of items relative to each other.

With the consensus of the experts, two hospitals that currently have a sufficient number of IT staff were identified as gold hospitals. After reviewing the information and repeating the classification and weighting steps, the final points of the hospitals were recalculated using the modified formula. Subsequently, it was observed that in these two hospitals, the ratio of the number of IT personnel to the final score of the hospital is almost 1 to 90. Therefore, the number of required IT personnel for each hospital was calculated by dividing the total points by 90. The final results underwent review and approval in the last focus group meeting.

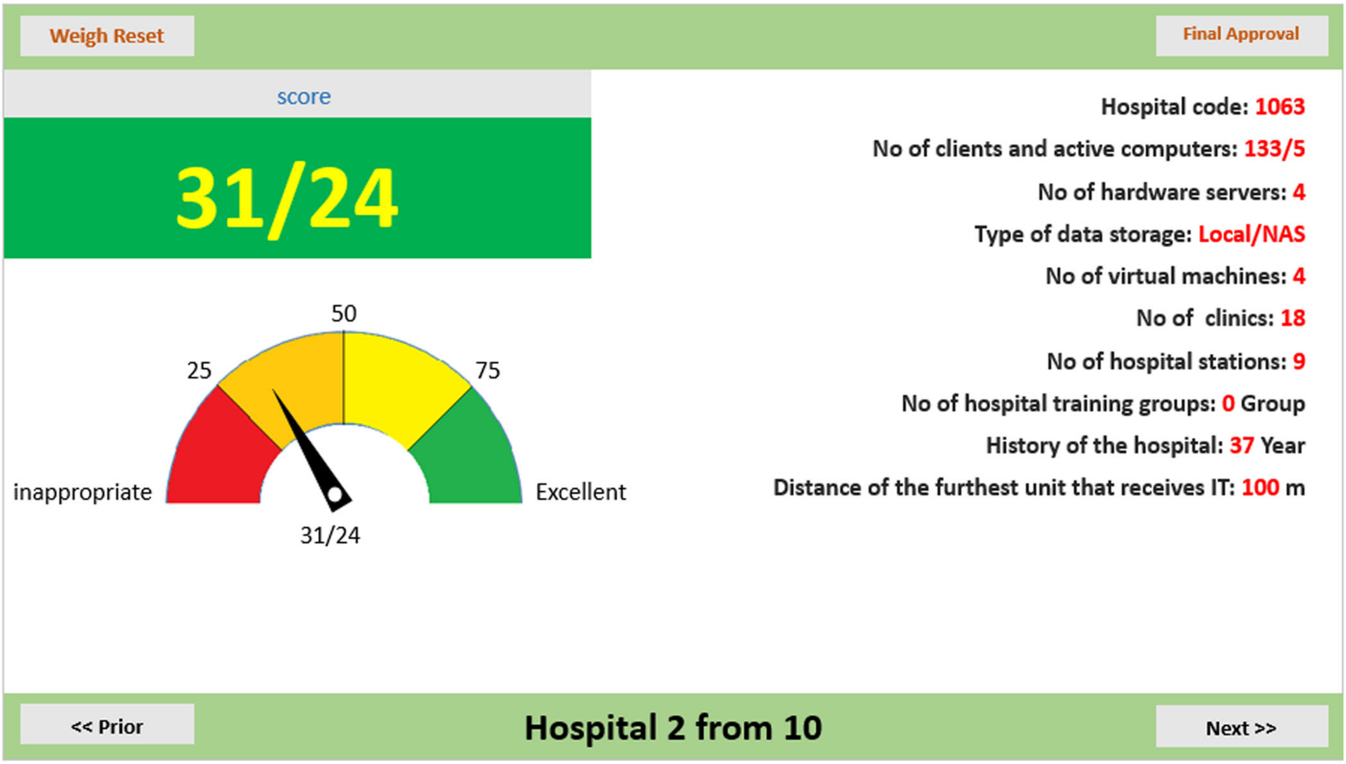

FIGURE 4 Hospitals information and scores. IT, information technology. IT, information technology; NAS, network attached storage.

3 | RESULTS

In this study, 10 university headquarters and hospital IT experts of Isfahan University of Medical Sciences were selected as Delphi members with the stated entry criteria. Four people (%40) of these experts were women and six others (%60) were men. The working experience of these people varies between 8 and 25 years with an average of 12.5 and a standard deviation of 5.35, and all of them had a Head position in the field of IT. Three of these specialists (%30) were working in the university headquarters and seven others were the heads of the IT units (single specialty hospitals [%20] and general hospitals [%50]). The selected hospitals were a combination of Isfahan hospitals (four hospitals [%57]) and other cities of Isfahan province (three hospitals [%43]), as well as a combination of single specialty (%29) and general (%71) hospitals. (Table 1). After the Delphi phase, the Focus Group Discussion including the study team and eight Delphi members kept on to the end of the study.

After gathering the factors affecting the number of IT staff needed by the hospitals in the interview phase, finally, 13 factors were given to the experts for scoring and conducting the first round of Delphi. In the first round, nine factors were confirmed including: the number of clients and active computers, the number of hardware servers, the type of data storage infrastructure, the number of active beds, the number of clinics, the number of hospital stations, the number of hospital training groups, the history of the hospital, and the distance of the furthest unit that receives IT services from the IT office. Four other factors were resent to the experts to be scored including: the number of modalities related to picture archiving and communication systems, the number of virtual machines, the type of activity of the hospital, and the distance from Esfahan. Only "the number of virtual machines" was confirmed in the second round and

TABLE 1 Demographic statistics of Delphi members.

Variable	Group	Frequency	Percent
Gender	Woman	4	40
	Man	6	60
Degree	Bachelor	2	20
	Master	8	80
Workplace	University headquarters	3	30
	Single specialty hospital	2	20
	General hospital	5	50
City	Isfahan	4	57
	Others	3	43
Field of study	Software CE	5	50
	Hardware CE	1	10
	Network technology CE	1	10
	Robotic machine intelligence CE	1	10
	IT	1	10
	Computer Sciences	1	10

Abbreviations: CE, computer engineering; IT, information technology.

the other factors were excluded from the study (Table A1). In addition, due to the high and significant correlation between "the number of computers" and "the number of active beds" ($r = 0.903$, $p < 0.001$), "the number of active beds" factor was removed from the list of influential factors.

The nine factors that remained in the study were discussed in Focus Group Disruptions. First, each factor was divided into classes which influenced the workload of IT staff, and then the weight of each class was determined (internal weighing w_i) (Table 2).

The factors, their classes, and the weight of each class were introduced to the ExPERT software. The experts valued them and finally, the relative importance of the factors (external weight) was calculated by the average of the experts' scores (α_i). "The number of computers" was the most effective factor with 32.18% and "the number of educational groups" was the least effective factor with 5.28% (Table 3).

Finally, the score of each hospital was calculated by applying the following formula:

the score of the jth hospital = $\sum_{i=1}^{9} \alpha_i \frac{w_{ij}}{\min w_i}$,

where α_i = the external weight of the ith factor; w_{ij} = the internal weight of the ith factor in the jth hospital; minw_i = the minimum of the internal weight of the ith factor

Dividing the above points by 90 (obtained by comparing the points and the current staff number of the standard hospitals), the required number of staff for each hospital was calculated (Table 4). As can be seen, 21 hospitals (approximately 57%) out of 37 hospitals of Isfahan University of Medical Sciences are facing a shortage of IT staff. This manpower shortage has varied between 0.5 and 1.6 personnel for different hospitals. 13 hospitals (approximately 35%) were reported with sufficient IT staff and three hospitals (8%) were reported with excess IT staff. The total number of personnel working in these hospitals is 19,333, with 148 dedicated to IT (74) and HIT (74) roles. This results in a ratio of 1 to 260 for IT personnel to total personnel and 1 to 130 for the combined number of IT and HIT personnel to total personnel across the 37 hospitals. Based on the study results, these ratios will change to 1 to 220 and 1 to 118 respectively.

TABLE 2 Classification and internal weighing of influential factors in determining the number of IT staff in hospitals (confirmed in the first or second phase of Delphi).

	Factor	Class	No. of involved hospitals	Weight (w_i)		Factor	Class	No. of involved hospitals	Weight (w_i)
1	No. of clients and active computers (computers with accessories were counted 1.5)	Up to 74 75–149 150–299 300–449 450–599 600–749 750–899 900–1050 1050–1200	7 14 10 3 2 0 0 0 1	0.11 0.17 0.28 0.39 0.50 0.61 0.72 0.84 1	6	No of clinics	Up to 19 20–30 31–40 more than 41	15 14 7 1	0.4 0.6 0.8 1
2	No of hardware servers	Up to 4 5–7 8–12 More than 12	18 13 5 1	0.5 0.7 0.85 1	7	No of hospital training groups	0 1–4 More than 5	27 6 4	0.2 0.5 1
3	Type of data storage infrastructure (The score of this factor will be the sum of the modes)	On the server Under the network (NAS) SAN TAPE	37 17 11 2	0.1 0.2 0.3 0.4	8	Distance of the furthest unit that receives IT	Up to 399 m 400–749 m 750–1099 m More than 1100 m	25 7 3 2	0.3 0.4 0.6 1
4	No. of virtual machines	0 Up to 5 6–10 11–20 21–30 More than 30	10 13 10 2 1 1	0.2 0.4 0.5 0.6 0.8 1	9	No. of hospital stations	2–8 9–15 16–22 23–40 More than 40	9 18 8 1 1	0.2 0.4 0.6 0.8 1
5	History of the hospital	Up to 15 years 16–40 41–80 More than 80	8 15 11 3	0.2 0.5 0.8 1					

Abbreviations: IT, information technology; NAS, network attached storage; SAN, storage area network.

TABLE 3 The results of MCDM using the ExPERT tool in valuing influential factors.

Experts	No. of clients and active computers	No. of hardware servers	Type of data storage infrastructure	No. of virtual machines	No. of clinics	No. of hospital stations	No. of hospital training groups	History of the hospital	Distance of the furthest unit that receives IT
Expert 1	23.9	12.5	8.3	11	12.5	12.5	6.3	5	8
Expert 2	28.8	11.9	10.2	11.9	11.9	10.2	6.8	3.4	5.1
Expert 3	48.5	8.5	7.5	6	9.25	9.25	3.5	3.5	4
Expert 4	34.30	12.00	7.00	6.00	10.00	14.00	5.00	7.10	4.60
Expert 5	28.4	16.2	10.2	6.2	10	10.9	0.6	8	9.7
Expert 6	43	15	8	11.3	6.2	5.4	3.4	4.6	2.8
Expert 7	27.8	9.5	6.5	6.5	14	15	8.6	4	8.1
Expert 8	22.7	11	9	11	11.3	11.3	8	7.7	8
Average (α_i)	32.18	12.08	8.34	8.74	10.64	11.07	5.28	5.41	6.29

Abbreviations: ExPERT, Expository Posthaste Effective Resemblant Tool; IT, information technology; MCDM, multi-criteria decision-making.

α_i

ω_{ij}

$\min \omega_i$

4 | DISCUSSION

In this study, we first specifically identified the factors affecting the workload of IT personnel in hospitals through interviews with a Delphi panel. As expected, the number of active computers and their accessories was the most important factor (with a weight of 32%) in this field, and it had a high correlation with the number of active beds in hospitals (which indicates the extent of their activities). In other words, the largest volume and working time of IT personnel are allocated to this factor. In 2017, Miguel Cruz and Guarin, while pointing out that to date, there is no accepted or accurate model for determining the appropriate number of manpower for clinical engineering departments (CEDs), demonstrated that by fitting a multivariate regression model, the total number of devices and the total hours devoted to these devices have a direct effect on the number of full time equivalents in a CED.[21] The next three effective factors, including the number of hardware servers, the number of hospital stations, and the number of clinics, each with almost equal scores, accounted for 33.5% of the total external weight. These three factors, akin to the first factor, underscore the significance of the size of the hospital and its impact on the workload of IT personnel. Following closely, the number of virtual machines and the type of data storage infrastructure, both with equal weights (8.5%), hold the next level of importance. While the utilization of virtual machines and modern storage infrastructures streamlines IT processes, the proliferation of virtual machines and the simultaneous usage of both modern and traditional storage infrastructures elevate the workload associated with IT maintenance and support activities. The distance to the farthest unit receiving IT services, the age of the hospital, and the number of educational groups within the hospital, each with relatively equal weights (approximately 6%), were ranked at the end of the list of identified factors. The first factor signifies the environmental size of the hospital. While some hospitals may have a moderate to low number of computers and consequently, a lower level of hospital activity, the Infrastructure area and dispersion of their buildings can prolong response times and the provision of IT services, particularly hardware and repair services. The age of the hospital, reflecting its structural features and infrastructure, significantly influences the installation and deployment of IT facilities. Often, aging buildings create disruptions in this regard, leading to process redundancies, longer implementation times, and increased workloads for IT personnel. Moreover, the expansion of training groups within the hospital leads to an uptick in IT activities related to the preparation and support of training classes, seminars, and associated webinars. In their 2022 systematic review, Pirrotta et al. highlighted the absence of a gold standard for assessing the needs of healthcare personnel, stressing the necessity of developing a comprehensive tool or model encompassing a sufficient array of variables to account for the characteristics of the healthcare landscape.[22] In this study, we endeavored to identify these variables within the realm of IT, resulting in the extraction, classification, and weighting of the aforementioned nine variables. A notable strength of this process lies in the inclusion of a broad and diverse spectrum of IT professionals as members of the Delphi and focus groups, facilitating a comprehensive review of the issue. To this end, a blend of seasoned and technical specialists from both university headquarters and affiliated hospitals, spanning geographical and activity level diversities (ranging from single-specialty to general hospitals), was carefully selected.

The use of the MCDM method is one of the strengths of this study. Moving beyond traditional approaches based solely on population and number of beds, the World Health Organization has

TABLE 4 The final score and the number of IT personnel required by 37 hospitals of Isfahan University of Medical Sciences based on the developed model.

Hospital	Final score	Predicted staff based on standard hospitals	Final predicted staff needed	No. of current personnel	Difference of predicted and current staff	Hospital	Final score	Predicted staff based on standard hospitals	Final predicted staff needed	No. of current personnel	Difference of predicted and current staff
Hospital 1	108.25	1.203	1.5	1	−0.5	Hospital 20	176.5	1.961	2	2	0
Hospital 2	108.50	1.206	1.5	1	−0.5	Hospital 21	177.42	1.971	2	2	0
Hospital 3	108.50	1.206	1.5	1	−0.5	Hospital 22	179.96	1.999	2	2	0
Hospital 4	108.50	1.206	1.5	1	−0.5	Hospital 23	198.17	2.202	2.5	2	−0.5
Hospital 5	111.00	1.234	1.5	1	−0.5	Hospital 24	208.77	2.320	2.5	2	−0.5
Hospital 6	118.92	1.321	1.5	1	−0.5	Hospital 25	217.01	2.411	2.5	1	−1.5
Hospital 7	125.71	1.396	1.5	1	−0.5	Hospital 26	230.21	2.558	2.5	2	−0.5
Hospital 8	133.75	1.486	1.5	1	−0.5	Hospita l27	234.01	2.600	2.5	2	−0.5
Hospital 9	139.21	1.547	1.5	1	−0.5	Hospital 28	237.51	2.640	3	4	1
Hospital 10	145.87	1.621	2	1	−1	Hospital 29	243.51	2.706	3	3	0
Hospital 11	152.76	1.700	2	2	0	Hospital 30	269.01	2.989	3	3	0
Hospital 12	155.62	1.729	2	2.1	0.1	Hospital 31	272.02	3.022	3	3	0
Hospital 13	155.71	1.730	2	2	0	Hospital 32	273.86	3.043	3	3	0
Hospital 14	159.87	1.776	2	2	0	Hospital 33	286.61	3.185	3.5	2	−1.5
Hospital 15	162.21	1.802	2	1	−1	Hospital 34	292.17	3.246	3.5	4	0.5
Hospital 16	167.01	1.856	2	1	−1	Hospital 35	302.51	3.361	3.5	2	−1.5
Hospital 17	167.21	1.858	2	2	0	Hospital 36	348.11	3.868	4	3	−1
Hospital 18	167.76	1.864	2	3	1	Hospital 37	577.91	6.421	6.5	4.9	−1.6
Hospital 19	171.96	1.911	2	2	0						

Abbreviation: IT, information technology.

globally developed and promoted the WISN methodology.[13] Due to its relative simplicity compared to previous methods, WISN has been widely adopted. Although the benefits derived from applying WISN outweigh the challenges of understanding and utilizing it, regional differences necessitate caution in generalizing results to other regions. Moreover, the quality of regional data is critical for its successful implementation.[14] In the affiliated units of the university, including its covered hospitals, statistics on the activities of IT experts are neither officially nor informally recorded and documented. Due to the broad spectrum of activities within this field, collecting new and reliable information can be time-consuming. Moreover, drawing from experiences with WISN implementation, it is suggested to initiate small-scale projects, such as starting in a hospital and then expanding to a wider level.[15] It should also be noted that implementing WISN in the hospitals of this university may result in a lower estimate of required manpower compared to the actual need. This discrepancy arises because some hospitals lack facilities or deploy IT personnel in unrelated areas, thereby reducing the volume of IT work and resulting in lower registration statistics than expected.[15] These factors prompted researchers to explore alternative methods for estimating manpower. Considering the multifaceted nature of IT personnel activities in hospitals, the use of the MCDM method appeared to be efficient. In recent decades, MCDM has garnered significant attention in various decision-making applications.[16] It has been demonstrated that individuals often struggle to make appropriate decisions when faced with diverse information.[23] MCDM is employed in scenarios where multiple factors influence the final decision. In this method, the objective is to simultaneously consider all these factors and, based on the ultimate goal, derive a solution that optimizes these factors.[16] In the present study, the MCDM method was employed to determine the external weights of identified factors. By amalgamating the obtained results, a mathematical model was devised to optimally ascertain the score of each hospital.

Another strength of the current study is the utilization of the ExPERT to facilitate MCDM in determining the external weight of factors influencing the workload of IT personnel. In general, there are a few ways to implement MCDM. In healthcare, the most commonly used method is the AHP.[16] Other important methods are: ELimination Et Choix Traduisant la REalite, PROMETHEE, Simple Multi-Attribute Rating Technique, and Technique for Order Preference by Similarity to Ideal Solution.[24–27] The mentioned methods have always been associated with shortcomings and complications. For example, AHP and PROMOTHEE which apply pairwise comparison of factors in factor weighing have the following shortcomings: first, the participants need specific training of this process, in addition limited memory capabilities and forgetting can lead to potential disruption in the correct allocation of weights and long-term interruptions. Also, the complexity of the process and the exponential increase in the number of pairwise comparisons by the increase of factors lead to a decrease in the user's accuracy. In addition, the weighing criteria in some of these methods are largely subjective. And some other methods require an additional predetermined threshold to compare different features to make a final decision.[28,29] In contrast, ExPERT is an efficient tool in MCDM. Using simple and favorable visual displays, it helps experts to employ their implicit knowledge in weighing factors dynamically and continuously. Furthermore, the use of this tool is simple and does not require complex training like other weighing methods. As a result, it saves the required time to determine the weight of various criteria. *When* using this tool, the experts can see the feedback of their opinions immediately and continuously in the form of visual charts, and make the necessary corrections if needed. *After* the completion of the weighing phase, the results of several cases that their data have already been provided to ExPERT software are examined based on their weighing, and if correction is needed, the determined weights are readjusted by experts.[17]

After utilizing the ExPERT tool and prioritizing hospitals based on the need for IT personnel, a few hospitals were selected as gold standard hospitals in focus group meetings. By calculating the standard ratio of points to IT personnel in these hospitals, the IT personnel requirements of other hospitals were estimated. According to the results, out of the 37 government hospitals covered by Isfahan University of Medical Sciences, approximately 57% (21 hospitals) were reported to have a shortage of IT personnel, while approximately 35% (13 hospitals) were deemed to have sufficient IT personnel, and 8% (three hospitals) were found to have an excess of IT personnel. One of the primary reasons for the lack of IT personnel in university hospitals is the predominant focus of hospital managers on the clinical domain, with insufficient attention to technical and infrastructure areas. Conversely, in hospitals where there is sufficient or excessive attention to the technical field, there tends to be adequate or excess personnel. This emphasis on clinical areas extends beyond hospital managers to senior managers of the Ministry of Health, as evidenced by the majority of allocated budgets being directed toward clinical staff recruitment. Several other factors contribute to the inadequate distribution of IT personnel in hospitals, including insufficient financial resources for recruitment, a shortage of employment permits in the IT field, the utilization of staff with inadequate skills, and their placement in nonspecialized positions.[1]

Ensuring the correct allocation of manpower is essential for hospital managers to effectively plan and distribute resources, thereby enhancing the quality of healthcare services and bringing departments up to standard levels.[5] The findings of this research can shed light on this aspect and potentially influence managerial policies. For instance, requests for personnel allocation can be scrutinized and validated based on the study results. To address shortages of IT staff in hospitals, various strategies can be implemented, such as transferring surplus staff from other hospitals, requesting additional recruitment budgets, planning for budget allocation and recruitment of corporate staff, outsourcing activities, and leveraging the expertise of HIT personnel. Additionally, for hospitals with adequate personnel but ongoing requests for additional staff, training programs to enhance the skills and capabilities of existing personnel or ensuring that they are engaged solely in specialized IT activities rather than unrelated tasks are recommended. Furthermore, based on the study findings, hospitals facing manpower shortages but not reporting their needs can be identified. Providing the necessary manpower to these hospitals can alleviate job stress, enhance IT personnel satisfaction, and increase productivity.

Based on the results obtained in the hospitals of this province, the ratio of total IT and HIT personnel to total personnel was 1 to 130. With the increase of IT personnel to the estimated values, this ratio becomes 1 to 118. The final ratio is almost twice the ratios reported in the United States of America (1 to 60), England (1 to 52), and Australia (1 to 48),[9] which highlights the volume and work pressure on the IT and HIT personnel of Isfahan hospitals. However, it's important to note that this study did not estimate the HIT workforce due to the description of the different tasks of these two groups. Additionally, the limited number of hospitals covered by Isfahan University of Medical Sciences (37 patients) constrained our ability to choose gold-standard hospitals. These two issues may impact the results of the study and the ratio of 1 to 118, as the score obtained by gold-standard hospitals directly affects the number of IT personnel needed by other hospitals. To address this limitation, it is suggested that the study be conducted on a wider level, such as at the national or international levels, and gold standard hospitals be selected from a larger community of hospitals.

The mathematical model introduced in this research not only estimates the required number of hospital staff based on existing facilities but also demonstrates the ability to rapidly adapt to changes in facility levels, enabling quick estimation of staffing needs under varying conditions. As such, this model stands as a comprehensive and dynamic tool for prioritizing hospitals in terms of IT personnel requirements and accurately estimating staffing needs. While the final results of this model received high approval from the focus group, it's important to note its sensitivity to the assigned internal weights. To enhance the accuracy of score estimation and consequently the determination of required personnel in future studies, meticulous attention should be given to defining and weighting the classes of each item, particularly the initial and final classes.

As previously noted, the absence of registration for IT activities and limited access to activity lists and their timing in Isfahan hospitals have posed challenges in implementing the WISN method, rendering it both challenging and time-consuming. However, the identified factors and findings of this research can serve as a foundation for defining the primary and support activities of IT personnel in hospitals. This could include activities related to identified factors like the computers, their accessories, servers, virtual machines, and so forth. By compiling a comprehensive list of these activities, efforts can be made to record the quantity and timing of activities in this domain. This data can then be utilized to assess the workload of IT personnel and facilitate the implementation of the WISN method for estimating the required number of IT personnel in hospitals.

5 | CONCLUSION

Making informed decisions regarding IT staffing needs in hospitals is complex due to numerous factors affecting this field. This study identified these factors by employing an experienced Delphi team and determined the importance of each using MCDM through the Expert tool. The most significant factors identified were the number of active computers and their accessories, the number of hardware servers, the number of hospital stations, and the number of clinics, respectively, with weights of 32%, 12%, 11%, and 10.5%, totaling 65.5% importance, indicating the scale of the hospitals. Other identified factors were related to hospital IT facilities (such as the number of virtual machines and the type of data storage infrastructure) as well as environmental facilities (the area and extent of hospital units and the age of the hospital). Additionally, a dynamic forecasting model for required IT staff in hospitals was presented based on the identified factors and their assigned importance. This method can be utilized in cases where workload-based methods like WISN are challenging or time-consuming, or when the lack of facilities leads to a decrease in workload and underestimation of workforce in WISN. The identified factors and results of this research can serve as a foundation for defining the primary activities, support, and additional IT staff for hospitals to implement WISN.

AUTHOR CONTRIBUTIONS

Majid Jangi: Conceptualization; methodology; software; project administration; supervision; funding acquisition; writing—review and editing. **Azadeh Shayan Babokani**: Supervision; writing—review and editing; writing—original draft; resources. **Mohsen Rezaei**: Formal analysis; data curation; investigation. **Shokouh Kamali Nasab**: Validation; data curation. **Morteza Mirzaei**: Validation; data curation. **Mozhgan Kazemzadeh**: Writing—original draft; writing—review and editing; data curation; investigation; resources; formal analysis.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

This study was ethically approved by the Ethical Committee of Isfahan University of Medical Sciences with the ethical code of IR.MUI.RESEARCH.REC.1401.231. No individual patient data was collected in the course of this study. IT expert participation was voluntary. Information on the study purpose, process, and outputs was provided to the panelists through a phone call. Verbal Informed consent was obtained from all panelists before their participation in this Delphi panel.

TRANSPARENCY STATEMENT

The lead author Mozhgan Kazemzadeh affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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APPENDIX A

TABLE A1 The results of the first and second rounds of Delphi in identifying the factors affecting the number of IT staff required by hospitals.

Round	Factor	Response percentage below 3	Response percentage above 7	Result
First	No. of clients and active computers	–	100	Agreement and approval
	No. of modalities related to PACS	–	50	Disagreement
	No. of hardware servers	–	90	Agreement and approval
	Type of data storage infrastructure	–	80	Agreement and approval
	No. of virtual machines	–	60	Disagreement
	No. of active beds	10	80	Agreement and approval
	No. of clinics	–	90	Agreement and approval
	Type of activity of the hospital (educational or noneducational)	10	60	Disagreement
	No. of hospital stations	–	90	Agreement and approval
	No. of hospital training groups	20	70	Agreement and approval
	Distance of the furthest unit that receives IT services from the IT office	–	100	Agreement and approval
	Distance from Esfahan	10	50	Disagreement
	History of the hospital	10	70	Agreement and approval
Second	No. of modalities related to PACS	10	50	Disagreement and deletion
	No. of virtual machines	–	80	Agreement and approval
	Type of activity of the hospital (Educational or noneducational)	–	30	Disagreement and deletion
	Distance from Esfahan	10	50	Disagreement and deletion

Abbreviations: IT, information technology; PACS, picture archiving and communication system.