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Research Article

Multiattribute Decision-Making of TQM Performance of Hospitals Using TQM Digraphs

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Total quality management (TQM) is a dynamic philosophy that incorporates gradual and uninterrupted improvements. The total quality is accomplished if all the desired goals including quality of product, reputation in market, services, low cost of product, employee and customer satisfaction, optimum utilization of resources, work environment, and so on are attained. As far as the Pakistani perspective is concerned, TQM as a strategic tool is not appropriately used to optimize its performance. Public healthcare in Pakistan is one of the most ignored sectors with regard to its service quality implementation and delivery. The public sector hospitals are one of the major primary healthcare providers, but the facilities they provide do not meet the desired requirement. This study addresses six TQM attributes to analyze the TQM performance of various public sector teaching hospitals in the province Punjab of Pakistan. The data was obtained from medical experts. The TQM performance to study the behavior of TQM implementation in hospitals is evaluated using TQM digraphs. The hospitals are ranked according to the TQM performance index, which is obtained from TQM digraphs. The technique to find the most effective attribute for a hospital is also proposed. The TQM digraph approach not only focuses on the significance of attributes independently but also incorporates the relative importance of one attribute over another. Also, this approach is very flexible that can incorporate new attributes and market variation so that continuous improvement may be possible. Moreover, the results obtained in this approach are not limited to beneficial for benchmarking of teaching hospitals in Punjab on the TQM basis, but these can also help indicate the particular attribute that is more needed to be improved for a particular hospital to increase its TQM performance.

1. Introduction

Health is in fact a basic requirement for any society and can be considered as the backbone of economic stability. Literature acknowledges the fact that improvement in health status is considered necessary for improving human welfare and human capital. Health not only enhances workers' productivity by increasing their physical capabilities but also enhances their mental capacities such as their reasoning and cognitive abilities that in turn play a pivotal role in sustainable economic growth [1]. Good health depends on a strong infrastructure of the healthcare system. For many underdeveloped countries including Pakistan, the healthcare issue is not considered just to overcome diseases, but it becomes more crucial and challenging in terms of efficiency and performance quality due to their limited resources.

1.1. Healthcare in Pakistan. Healthcare expenditure in Pakistan is increasing significantly and turning into big investments for escalation of quality of healthcare services across the country. Pakistan's national health policymakers are keen to devise and review the health services structure at different levels in changing environments and time frames. The objective behind is to attain and sustain the optimal level of efficiency and relative productivity in the delivery of healthcare services. Healthcare expenditure in Pakistan is increasing significantly and turning into big investments for escalation of quality of healthcare services across the

country. The healthcare system of Pakistan comprises public and private health systems. Private hospitals are providing world-standard healthcare system owing to their huge resources and facilities. The private health sector comprises non-governmental organizations (NGOs), charitable organizations, trusts, and corporate health sectors. The increase in the private healthcare system is due to the massive difference between the contribution of health services of public and private health sectors. Most of the patients prefer to visit private hospitals because public hospitals cannot fulfill the criteria of services [2]. The inefficiency of the public health sector provides a chance for the private health sector to expand healthcare services to commercialization and commoditization of the medical sector [3]. According to the Economic Survey of Pakistan (2018–2019), only 1.1% of its GDP is allocated for healthcare expenditures by the government. The district health system under the district government is now liable for planning, development, and management along with the implementation of healthcare delivery from DHQ hospitals right down to the outreach programs. Despite the detailed and complex network of healthcare delivery, Pakistan has fallen short to bring about an enhancement in health status, especially of rural population. The health system of Pakistan is described by insufficient expenditure, low-quality service, and poor utilization of services. The three most popular reasons for these are unavailable facilities, non-availability of medicines, and low-skilled staff. In the public sector, 947 hospitals, 4,800 dispensaries, and 1,084 MCH center are mostly located in urban and semiurban areas; on the other hand, 581 RHCs and 5,798 BHUs are providing services to the population of rural areas. The total number of availability of beds is approximately 101,047. The inadequate number of health workers in Pakistan is summarized in Table 1 (Economic Survey of Pakistan (2018–2019).

Table 1: Registered medical and paramedical personnel.

Health workers	Numbers in 2019
Doctors	233,261
Nurses	112,123
Dentists	24,930
Midwives	41,810
Lady health visitors	20,565

1.2. Healthcare in Punjab. Among the other provinces of Pakistan, Punjab has achieved substantial progress in the field of health. Punjab has become a model for other provinces in the context of low maternal and infant rate and low birth and death rate. The Punjab province comprises 2,455 basic health units (BHUs) and 293 rural health centers (RHCs) in an open area. There are 42 public sector teaching hospitals in 13 districts (9 divisions) of Punjab, and among 42, 3 are purely dental hospitals. The detailed listing of the remaining 39 hospitals is given in Table 2.

2. Total Quality Management (TQM)

Total quality management (TQM) is an effective philosophy that integrates subtle and continuous development. It can be seen as a corporate-level philosophy such that each employee must focus his input on improving the commercial movements of a company [4]. The total quality is accomplished if all the desired goals including quality of product, process, reputation in market, services, material, low cost of product, employee satisfaction, policies, customer satisfaction, optimum utilization of resources, work environment and functional area, and so on of an organization are attained. These objectives can be obtained by planning, setting targets, affecting agents, improving support systems, applying different techniques, considering human factors, using modern tools, and so on. Mersha [5] emphasized that most crucial and needed objective, i.e., customer satisfaction, can be attained through continuous improvement, maximum participation and involvement of all stakeholders of the company. According to Dale and Cooper [6], TQM measures must include the participation of every person in the organization, teamwork, customer satisfaction, and training programs. Taveiraa et al. [7] suggested that the efficiency of TQM in an organization might depend on the human factor. Motivated by its inspiring outcomes in different service sectors as well as in manufacturing organizations, TQM is also applied in healthcare organizations. Short and Rahim [8] suggested that before the implementation of TQM in any healthcare organization, the rules, procedures, and structures need to be redefined. Another study by Muhhurrum et al. [9] indicated that patients' needs must be taken into account while implementing TQM. The study of Indian hospitals emphasized that cultural, political leadership, and attitude of the healthcare professionals are obstacles to the implementation of TQM, and these factors need to be resolved [10]. Several attempts have been made to implement TQM factors in the healthcare system across the world, but almost no significant attempt has been done so far in the Pakistani healthcare system [11, 12]. Irfan et al. (2011, 2011a) emphasized that private hospitals are providing a better quality of healthcare services in contrast to public sector hospitals. Irfan et al. [13] conducted a study on Pakistani public sector hospitals and stated that the well-mannered implementation of TQM can significantly increase the productivity of processes in Pakistani hospitals. The literature indicates that management practices and their basic principle affect directly to the patients' satisfaction [14]. Talib et al. [15] employed four TQM practices in the service environment, and in [16], it is recognized that these TQM practices are among the best practices for effective implementation of TQM in both service and manufacturing industries. Yasin et al. [17] studied the effectiveness of the implementation of TQM practices in service organizations. Now, it is in dire need of Pakistani health policymakers to implement TQM practices in the Pakistani healthcare system.

Various techniques and models are used for this study, but graph-theoretic approach being a mathematical model produces the scientific and most accurate results, and generalization of these results in different areas of service sectors is extremely helpful. Moreover, this approach is very flexible and can incorporate new attributes and market

Table 2: List of public sector hospitals in Punjab.

Sr. No.	Hospitals	District
1	Jinnah Hospital (JH)	Lahore
2	Sheikh Zayed Hospital (SZH)	Lahore
3	Services Hospital (SH)	Lahore
4	Government Nawaz Sharif Hospital (GNSH)	Lahore
5	Lahore General Hospital (LGH)	Lahore
6	Said Mitha Hospital (SMH)	Lahore
7	Government Mozang Teaching Hospital (GMTH)	Lahore
8	Lady Aitchison Hospital (LAH)	Lahore
9	Children Hospital (CHL)	Lahore
10	Lady Willington Hospital (LWH)	Lahore
11	May Hospital (MH)	Lahore
12	Punjab Institute of Cardiology (PIOC)	Lahore
13	Sir Ganga Ram Hospital (SGRH)	Lahore
14	Government Mian Munshi Hospital (GMMH)	Lahore
15	Government Kot Khawaja Saeed Teaching Hospital (GKKSTH)	Lahore
16	Govt Teaching Hospital Shahdra (GTHS)	Lahore
17	Government Sardar Begum Teaching Hospital (GSBTH)	Sialkot
18	Aziz Bhatti Saeed Hospital (ABSH)	Gujrat
19	District Head Quarter Hospital Gujranwala (DHQHG)	Gujranwala
20	Wazirabad Institute of Cardiology (WIC)	Wazirabad
21	District Head Quarter Hospital Rawalpindi (DHQH)	Rawalpindi
22	Holy Family Hospital (HFH)	Rawalpindi
23	Benazir Bhutto Hospital (BBH)	Rawalpindi
24	Rawalpindi Institute of Cardiology (RIOC)	Rawalpindi
25	Allied Hospital (AH)	Faisalabad
26	District Head Quarter Hospital Faisalabad (DHQHF)	Faisalabad
27	Govt General Hospital Ghulam Muhammad Abad (GGHGMA)	Faisalabad
28	Faisalabad Institute of Cardiology (FIC)	Faisalabad
29	Children Hospital, Faisalabad (CHF)	Faisalabad
30	District Head Quarter Hospital Sargodha (DHQHS)	Sargodha
31	District Head Quarter Hospital Sahiwal (DHQHS)	Sahiwal
32	Nishtar Hospital (NH)	Multan
33	Ch. Pervaiz Elahi Institute of Cardiology (CPEIC)	Multan
34	Children Hospital Mulatan (CHM)	Multan
35	Bahawal Victoria Hospital (BVH)	Bahawalpur
36	Cardiology and Cardiac Surgery Hospital (CCSH)	Bahawalpur
37	Civil Hospital Bahawalpur (CHB)	Bahawalpur
38	Sheikh Zayed Medical Hospital (SZMH)	Rahim Yar Khan
39	Teaching Hospital Dera Ghazi Khan (THDGK)	D.G. Khan

variations so that continuous improvement may be possible. According to Baykasoglu [18], the most promising feature of this technique is its interfacing behavior and its capability to represent hierarchical models in a better way. He also revealed the applications of GTA in decision-making problems. Grover et al. [19, 20] used the graph-theoretic approach for industry evaluation and to investigate the consequences of human factors in the implementation of TQM. Kulkarni [21] also used this technique for performance evaluation of Indian industries. Anand and Bahinipati [22] used the graph-theoretic approach to measure horizontal collaboration intensity in the supply chain. Singh et al. [23] used this graph-theoretic approach in assessing the quality of manufacturing organizations. Jangra et al. [24] used GTA for the performance evaluation of carbide compacting die. The same technique is also used to evaluate the machinability of tungsten carbide composite with wire EDM [25]. The multicriteria decision-making approach in quality assessment is discussed in [26–30]. Different fuzzy graph-theoretic models are also used in several decision-making problems [31–37].

The aim of this study is to evaluate the TQM performance of public sector hospitals of province Punjab of Pakistan using graph-theoretic technique.

3. TQM Attributes

The TQM attributes that are considered in the performance evaluation of the public sector hospitals in Punjab are briefly discussed.

3.1. Top Leadership Commitment. A solid foundation for implementing TQM operations will be laid by strong leadership. Since everyone's involvement is a requirement for implementing TQM in hospitals, management must exercise leadership skills to influence the behavior of others in hospitals. TQM succeeds in organizations through continuous

purposeful leadership, interteam communication, and full senior management commitment focused on customer satisfaction. Good leadership has the ability to build a strong foundation, develop and lead a long-term vision of the organization, and focus on ever-changing customer needs.

3.2. Continuous Improvement. It stands for devotion to the continuous analysis of the administrative and managerial process so that more appropriate methods can be replaced with existing processes. In other words, flaws can be identified so that mistakes can be evaded. In the healthcare industry, through continuous improvement, all the team members (CMOs, doctors, paramedical staff, administrative staff, etc.) of a hospital can be engaged in designing improvement strategies and their implementation.

3.3. Performance Management System. Through the performance management system, an organization can gain and maintain its competitive advantages and improve its resilience and future prospects. In the healthcare industry, it is based on the number of things such as economy, productivity, and efficacy due to the variation of interests of many stakeholders such as doctors, financers, and trusts. Through this, hospital management can identify the areas for performance improvements, planning systematic performance improvement initiatives, setting targets, and continuously tracking metrics.

3.4. Employee Empowerment. The empowerment of a team can develop the best collaboration among the team, which in turn led to innovation. Through employee empowerment, the individual skills, proficiency, and initiative attitude can be linked to wider social policies of hospitals in a better way. Moreover, this motivates the employees to ascertain the best line of action in every context to acquire the desired goals set forth by the management.

3.5. Effective Operational Management. Proper operations management can help overcome a variety of obstacles so one can provide excellent customer service at every level. The importance of operations management in healthcare cannot be overstated as the healthcare industry is incredibly diverse and operations often require unique solutions based on a variety of factors. Operations management in healthcare refers to overseeing the day-to-day practices of a healthcare facility that impact the client experience and organizational goals.

3.6. Patient Satisfaction. One of the important requirements of TQM is to cultivate customer-oriented operational processes. Filippini and Forza [38] suggested that it is far essential for an organization to preserve close bondage with their clients on the way to recognize their necessities and measure how it has been a success in meeting up to clients' necessities. Client satisfaction is considered as the most important element for healthcare suppliers as well as for patients themselves within the medical care commercial community [39]. Aliman and Mohamad [40] claimed that the quality performance of healthcare units is positively interrelated with patient satisfaction.

4. Graph-Theoretic Approach (GTA)

The graph-theoretic approach is used to evaluate the TQM performance of public sector hospitals. Graph theory is an elegant way to describe any network or model.

> Definition: A graph comprises nodes (representing the basic components of the model), and edges indicate the relation between the nodes.
>
> Definition: A directed graph or a digraph is a graph in which the edges have a direction. This is usually indicated with an arrow on the edge, more formally, if v and w are vertices, an edge is an unordered pair $\{v, w\}$, while a directed edge, called an arc, is an ordered pair (v, w) or (w, v).

The graph-theoretic approach is systematical mathematical modeling that incorporates all the qualitative properties and factors of the given problem into mathematical quantities. This makes them more effective than other techniques such as flow charts, cause-effect diagrams, and so on. To study the TQM environment, GTA not only emphasizes on the numerical values of TQM factors in the TQM environment but also includes the influencing relation of one factor over another. In this approach, the qualitative information of the TQM evaluation process is converted into a numerical quantity known as the hospital TQM performance index (HTQMPI). This index is not only used to evaluate the quality performance of hospitals under study but can also be used in ranking these hospitals in terms of TQM attributes. This method elegantly incorporates the significance of attributes and their relative importance for a given organization. This graph-theoretic approach comprises the following three main components.

4.1. TQM Attributes Digraph D_{TQM}. It consists of a set of nodes v_i with $i = 1, \cdots M$ having TQM attribute value A_i and a set of arcs with edge weight A_{ij} that indicates the interdependency or relative importance of i-th attribute over j-th attribute. If an attribute A_i (node i) is relatively more important than the attribute A_j (node j), then a directed arc is drawn from node i to node j with arc weight A_{ij}.

4.2. TQM Variable Permanent Matrix PM_{TQM}. Although TQM attributes digraph provides a graphical representation of the attributes and their interdependency relation, it would be difficult to visualize these digraphs if the number of attributes increases. However, this problem can be settled by representing the attribute digraph by an $M \times M$ matrix. This matrix sufficiently incorporates all the characteristics of the attribute digraph including the attribute values and their relative importance. Suppose there are M values of attributes $A_1, \ldots, A_M$. Then the general TQM variable permanent matrix for M-TQM attributes environment is defined as

$$PM_{TQM} = \begin{bmatrix} A_1 & \cdots & A_{1M} \\ \vdots & \ddots & \vdots \\ A_{M1} & \cdots & A_M \end{bmatrix}. \quad (1)$$

4.3. TQM Performance Index, TQM_{HPI}. The TQM performance index, TQM_{PI}, is a numerical value that is used to evaluate the TQM performance of a hospital. It is obtained through the permanent function of the TQM variable permanent matrix defined as follows:

$$per\left(PM_{TQM}\right) = \sum_{\sigma} \prod_{i} A_{i\sigma(i)}, \quad (2)$$

where σ is a permutation on M attributes and $A_i = A_{ii}$. The permanent function of PM_{TQM} for five TQM attributes environment is defined as follows:

$$\begin{aligned} per\left(PM_{TQM}\right) = {} & \prod_{i=1}^{5} A_i + \sum_i \sum_j \sum_k \sum_l \sum_m \left(\left(A_{ij}A_{ji}\right)A_kA_lA_m \right. \\ & + \left(A_{ij}A_{jk}A_{ki} + A_{ik}A_{kj}A_{ji}\right)A_lA_m \\ & + \left(A_{ij}A_{ji}\right)\left(A_{kl}A_{lk}\right)A_m \\ & + \left(A_{ij}A_{jk}A_{kl}A_{li} + A_{il}A_{lk}A_{kj}A_{ji}\right)A_m \\ & + \left(A_{ij}A_{ji}\right)\left(A_{kl}A_{lm}A_{mk}\right) + A_{km}A_{ml}A_{lk} \\ & \left. + A_{ij}A_{jk}A_{kl}A_{lm}A_{mi} + A_{im}A_{ml}A_{lk}A_{kj}A_{ji}\right). \end{aligned} \quad (3)$$

The above expression is appropriate for TQM evaluation as it involves both the values of attributes and their interrelationship impact. Its numerical value gives the TQM performance index, TQM_{HPI}:

$$TQM_{HPI} = per\left(PM_{TQM}\right). \quad (4)$$

Since it contains only positive terms and values of A_i, A_{ij} are also non-negative, and its higher value indicates the better performance of an organization.

5. Quantification of A_i' s and A_{ij}' s

To compute TQM_{HPI}, the values of A_i' s and A_i' s need to be calculated. The organizations that are evaluated through TQM attributes provide the data, and then such data are converted into a suitable qualitative scale (0–10). If it is difficult to measure attributes through a qualitative scale, then a questionnaire may be designed to measure their values. In this case, these quantitative values are then normalized so that qualitative and quantitative scales remain the same, that is, 0–10. The values of A_i' s indicating the relative importance of the TQM factors are also allocated on a scale 0–10. These values can be assigned according to the rule given in Table 3.

6. Advantages of Proposed Method

The TQM digraph approach has the following advantages:

(i) The benefit of GTA to study TQM environment is that this method not only highlights the importance of all TQM attributes independently but also focuses on the interdependence and relative importance of one attribute over another.

(ii) This approach is not limited to pictorial analysis but is also suitable for computer processing as matrices are involved in the proposed technique.

(iii) As the obtained results are in the form of numerical values, in this way, the comparison and benchmarking of hospitals are very easy and useful.

(iv) The proposed method can integrate multiattributes at a time.

(v) The graph-theoretic approach is systematical mathematical modeling that incorporates all the qualitative properties and factors of the given problem into mathematical quantities. This gives superiority to the proposed method over conventional methods such as flow charts, cause-effect diagrams, and so on.

(vi) The proposed technique also helps indicate the particular set of attributes that are more influential than other attributes or that are more needed to be improved for a particular hospital to improve its TQM performance subsequently.

Table 3: Values for A_{ij}' s.

Relative importance	A_{ij}	A_{ji}
Same importance	5	5
i-th attribute is slightly important than j-th	6	4
i-th attribute is very important than j-th	7	3
i-th attribute is most important than j-th	8	2
i-th attribute is extremely important than j-th	9	1
i-th attribute is extraordinary important than j-th	10	0

7. Limitations of the Study

One of the limitations of this study is the limited number of hospitals in the Punjab province. There are total 8,300 public sector healthcare facilities in Punjab, but this study deals only with 39 teaching/public hospitals in Punjab due to the unavailability of data from other healthcare facilities. Another limitation of this study is that the data is collected only from healthcare professionals. This small sample size may limit the generalizability of the results of the study. The more accurate results can be obtained if the sample size is increased by taking data from healthcare professionals as well as from the management team and patients who are the actual stakeholders.

8. Methodology

A questionnaire addressing six TQM factors was developed. The data were collected from healthcare professionals working in the under studied hospitals. The following main steps for the assortment of best TQM performing public sector hospitals among the hospitals in nine divisions of Punjab, Pakistan, and to determine the influential attribute

that contributed most significantly to the TQM index of hospitals as compared to others are proposed:

Step 1: For an assortment of the best TQM performing public sector hospital:

(1) The list of suitable attributes to evaluate the TQM performance of a hospital is identified.
(2) The values of each attribute A_i is computed using a questionnaire. These values are then normalized as follows:
Let $a_{il} \le A_i \le a_{iu}$, that is, a_{il} and a_{iu} are minimum and maximum values of A_i, respectively. Then for any intermediate value a_{ik} of the attribute A_i is normalized as

$$A_i = \begin{cases} 10 \times \dfrac{a_{ik}}{a_u}, \text{ if } a_{il} = 0, \\ \\ 10 \times \left(\dfrac{a_{iu} - a_{ik}}{a_{iu} - a_{il}} \right), \text{ otherwise.} \end{cases} \quad (5)$$

For the values of relative importance A_{ij}, among the attributes, see Table 3 for details.
(3) Construct the TQM attributes digraph for each hospital by taking the selected TQM performance attributes as vertices. The edges and their directions are drawn according to the values of A_{ij}.
(4) Construct the TQM variable permanent matrix for selected TQM attributes for each hospital as given in (1).
(5) Formulate the TQM performance index, TQM_{HPI}, as given in (2).
(6) Evaluate the TQM performance index, TQM_{HPI}, for each hospital by putting the values of $A_{\mathbf{i}}'$ s and $A_{\mathbf{ij}}'$ s, which are attained in step 2 into the expression obtained in step 5.
(7) Sort out the hospitals in descending order of the TQM performance index, TQM_{HPI}.
The hospital with the highest TQM performance index, TQM_{HPI}, value can be considered the best hospital in terms of TQM implementation.

Step 2: For finding the most influential attribute in a hospital:

(1) To find the contribution of an attribute A_i in the TQM index, all the terms in the expression (2) containing A_i are evaluated. For this, construct digraph D_{TQM-A_i}, which is obtained by removing the vertex corresponding to attribute A_i.
(2) The permanent matrix PM_{TQM-A_i} for the digraph D_{TQM-A_i} is constructed from (1) by deleting the i-th row and column.
(3) Formulate the TQM index of attribute A_i as follows:

$$TQM_{A_iPI} = A_i \times per\left(PM_{TQM-A_i}\right). \quad (6)$$

(4) Evaluate TQM_{A_iPI} for each attribute of every hospital by putting the already calculated values of $A_{i,}$ s and A_{ij}' s, into the expression obtained in the previous step.
(5) Sort out the attributes of each hospital in descending order of TQM_{A_iPI}. The attribute with highest TQM_{A_iPI} value is considered as the most influential attribute for that hospital.

Step 3: For determining the independent TQM implementation of individual attributes among hospitals:

(1) Formulate the percentage contribution of attribute A_i in TQM_{HPI} as

$$TQM_{PA_iPI} = 100 \times \frac{TQM_{A_iPI}}{TQM_{HPI}}. \quad (7)$$

(2) Evaluate TQM_{PA_iPI} by putting already computed values of TQM_{A_iPI} and TQM_{HPI} in the above expression for each hospital.
(3) The hospital with the highest value of TQM_{PA_iPI} is considered as having the best implementation of attribute TQM_{PA_iPI} in that hospital.
(4) Compute the average value of TQM_{A_iPI}. The attribute with highest TQM_{A_iPI} is considered as the best implemented TQM attribute all over the province Punjab.

9. Analysis and Results

Based on the financial, physical, and regional conditions of the public sector hospitals in Punjab, the following six TQM attributes that could affect the TQM performance of the under studying hospitals are selected:

(i) A_1 – top leader management (TLM)
(ii) A_2 – continuous improvement (CI)
(iii) A_3 – performance management system (PMS)
(iv) A_4 – employee empowerment (EE)
(v) A_5 – effective operational management (EOM)
(vi) A_6 – patient satisfaction (PS)

The required data were taken from the hospitals through a designed questionnaire. Each attribute in the questionnaire is assessed through eight subquestions, where each subquestion has maximum of five points that further contributed total of 40 points to each attribute. As all six attributes are beneficial in our graph-theoretic model, therefore, their higher values are required. The point values of each attribute A_i for $i = 1, 2, 3, 4, 5, 6$ is calculated for all 39 hospitals. These values are then converted into the 0–10 scale (normalized) as defined in (5). The values of relative importance A_{ij} of attribute A_i over attribute A_j from 0 to 10 based on the literature review and the physical situation of these hospitals are then assigned according to Table 3. For instance, TLM is more important than EE so a relatively higher value of 6 of relative importance is given to the TLM over EE, and the low value of 4 of relative importance is given to the EE over the TMS. Likewise, all other relative importance between the other attributes can be illustrated. The values of relative importance among six attributes are given in Table 4.

The TQM digraph, where the six nodes represent the selected attributes A_i' and directed edges show the relative importance, is depicted in Figure 1.

Table 4: Relative importance among six attributes.

Attributes	A_1	A_2	A_3	A_4	A_5	A_6
A_1	—	6	6	4	6	4
A_2	4	—	6	4	6	5
A_3	4	4	—	4	5	6
A_4	6	6	6	—	7	6
A_5	4	4	5	3	—	7
A_6	6	5	4	4	3	—

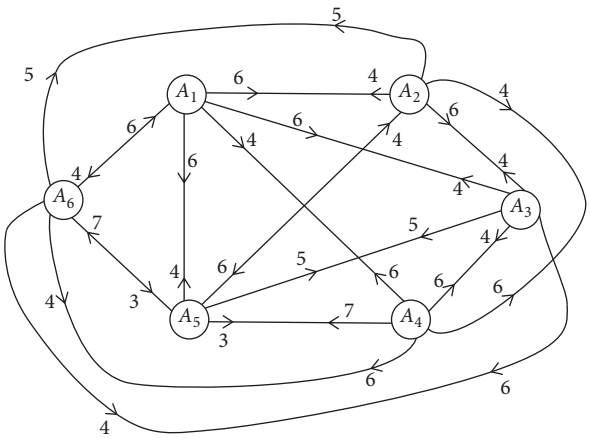

Figure 1: The digraph D_{TQM} for six attributes.

The TQM permanent matrix for each hospital using expression (1) is written as

$$PM_{TQM} = \begin{pmatrix} A_1 & A_{12} & A_{13} & A_{14} & A_{15} & A_{16} \\ A_{21} & A_2 & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{31} & A_{32} & A_3 & A_{34} & A_{35} & A_{36} \\ A_{41} & A_{42} & A_{43} & A_4 & A_{45} & A_{46} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_5 & A_{56} \\ A_{61} & A_{62} & A_{63} & A_{64} & A_{65} & A_6 \end{pmatrix}. \tag{8}$$

The permanent TQM index for each hospital is expressed as:

$$\begin{aligned} TQM_{HPI} &= per\left(PM_{TQM}\right) \\ &= \prod_{i=1}^{6} A_i + \sum_i \sum_j \sum_k \sum_l \sum_m \left(\left(A_{ij}A_{ji}\right)A_kA_lA_mA_n + \left(A_{ij}A_{jk}A_{ki} + A_{ik}A_{kj}A_{ji}\right)A_lA_mA_n \right. \\ &\quad + \left(A_{ij}A_{ji}\right)\left(A_{kl}A_{lk}\right)A_mA_n + \left(A_{ij}A_{jk}A_{kl}A_{li} + A_{il}A_{lk}A_{kj}A_{ji}\right)A_mA_n + \left(A_{ij}A_{ji}\right)\left(A_{kl}A_{lm}A_{mk}\right) \\ &\quad + A_{km}A_{ml}A_{lk}A_n + \left(A_{ij}A_{jk}A_{kl}A_{lm}A_{mi} + A_{im}A_{ml}A_{lk}A_{kj}A_{ji}\right)A_n + \left(A_{ij}A_{ji}\right)\left(A_{kl}A_{lk}\right)\left(A_{mn}A_{nm}\right) \\ &\quad + \left(A_{ij}A_{jk}A_{kl}A_{li} + A_{il}A_{lk}A_{kj}A_{ji}\right)\left(A_{mn}A_{nm}\right) + \left(A_{ij}A_{jk}A_{ki} + A_{ik}A_{kj}A_{ji}\right) + \left(A_{lm}A_{mn}A_{nl} + A_{\ln}A_{nm}A_{ml}\right) \\ &\quad \left. + \left(A_{ij}A_{jk}A_{kl}A_{lm}A_{mn}A_{ni} + A_{in}A_{nm}A_{ml}A_{lk}A_{ki}\right). \right. \end{aligned} \tag{9}$$

The quantitative values of the above six mentioned attributes calculated from the questionnaire are given in Table 5. The normalized values of these attributes are detailed in Table 6. The values of A_i' s and A_{ij}' given in Tables 4 and 6, respectively, and the expression given in (9) are used to compute the TQM performance index, TQM_{HPI}, for each hospital.

All the computations are carried out in MATLAB using constructed TQM permanent matrix expressed in (8) for each hospital. The values of the permanent index for all hospitals are tabulated in Table 7. The TQM index-based ranking of public sector teaching hospitals in Punjab is shown in Figure 2.

Now, to find the TQM index of each attribute of a hospital, the digraph D_{TQM-A_i} and permanent matrix PM_{TQM-A_i} are constructed using the values of $A_i s$ and A_{ij}' s from Tables 4 and 6 as detailed in the methodology section. For example, consider Lahore General Hospital and attribute A_1. The digraph D_{TQM-A_i} is given in Figure 3.

The matrix PM_{TQM-A_1} is given as

Table 5: Numerical values of attributes.

Sr. No.	Hospitals	A_1	A_2	A_3	A_4	A_5	A_6
1	JH	30	28	30	32	32	28
2	SZH	32	33	36	32	34	33
3	SH	34	36	31	33	35	35
4	GNSH	35	31	30	35	35	33
5	LGH	31	32	30	30	30	32
6	SMH	27	30	30	28	28	33
7	GMTH	26	28	28	26	26	30
8	LAH	30	28	30	29	29	28
9	CH	30	34	33	32	35	32
10	LWH	25	26	28	26	32	30
11	MH	33	32	32	31	35	33
12	PIC	32	35	28	31	34	28
13	SGRH	35	33	30	27	30	25
14	GMMH	16	16	15	18	20	20
15	GKKSTH	12	18	16	16	22	22
16	GTHS	18	12	14	15	24	20
17	GSBTH	21	19	21	19	19	18
18	ABSH	19	19	19	18	21	17
19	WIC	30	23	22	23	24	26
20	DHQHG	26	22	26	21	26	23
21	DHQHR	25	25	14	12	16	17
22	HFH	30	28	20	18	22	24
23	BBH	25	25	13	10	13	15
24	RIC	32	25	24	22	25	28
25	AH	29	28	23	22	28	29
26	DHQHF	23	24	25	23	24	25
27	GGHGMA	22	21	26	21	23	25
28	FIC	29	28	25	26	25	27
29	CH	28	25	27	28	27	29
30	DHQHS	15	12	12	10	10	8
31	DHQHS	19	5	21	18	20	17
32	NH	26	22	20	23	22	25
33	CPEIC	25	28	22	20	27	26
34	CH	25	22	23	17	23	27
35	BVH	23	26	18	18	22	24
36	CCSH	23	25	24	26	25	28
37	CHB	18	15	18	10	15	10
38	SZMH	20	18	10	18	15	18
39	THDGK	15	13	8	13	10	13

Table 6: Normalized values of attributes.

Sr. No	Hospitals	A_1	A_2	A_3	A_4	A_5	A_6
1	JH	8	7	8	9	9	7
2	SZH	9	9	10	9	10	9
3	SH	10	10	8	9	10	10
4	GNSH	10	8	8	10	10	9
5	LGH	8	9	8	8	8	9
6	SMH	7	8	8	7	7	9
7	GMTH	6	7	7	6	6	8
8	LAH	8	7	8	8	8	7
9	CH	8	9	9	9	10	9
10	LWH	6	7	7	6	9	8
11	MH	9	9	9	8	10	9
12	PIC	9	10	7	8	10	7
13	SGRH	10	9	8	7	8	6
14	GMMH	2	4	3	3	4	4
15	GKKSTH	0	4	3	2	5	5
16	GTHS	3	2	2	2	6	4
17	GSBTH	4	5	5	4	4	4
18	ABSH	3	5	4	3	4	3
19	WIC	8	6	5	5	6	7
20	DHQHG	6	5	6	4	6	6
21	DHQHR	6	6	2	1	2	3
22	HFH	8	7	4	3	5	6
23	BBH	6	6	2	0	1	3
24	RIC	9	6	6	5	6	7
25	AH	7	7	5	5	7	8
26	DHQHF	5	6	6	5	6	6
27	GGHGMA	4	5	6	4	5	6
28	FIC	7	7	6	6	6	7
29	CH	7	6	7	7	7	8
30	DHQHS	1	2	1	0	0	0
31	DHQHS	3	0	5	3	4	3
32	NH	6	5	4	5	5	6
33	CPEIC	6	7	5	4	7	7
34	CH	6	5	5	3	5	7
35	BVH	5	7	4	3	5	6
36	CCSH	5	6	6	6	6	7
37	CHB	3	3	4	0	2	1
38	SZMH	3	4	1	3	2	4
39	THDGK	1	3	0	1	0	2

$$PM_{TQM} = \begin{pmatrix} A_2 & A_{23} & A_{24} & A_{25} & A_{26} \\ A_{32} & A_3 & A_{34} & A_{35} & A_{36} \\ A_{42} & A_{43} & A_4 & A_{45} & A_{46} \\ A_{52} & A_{53} & A_{54} & A_5 & A_{56} \\ A_{62} & A_{63} & A_{64} & A_{65} & A_6 \end{pmatrix} = \begin{pmatrix} 9 & 6 & 4 & 6 & 5 \\ 4 & 8 & 4 & 5 & 6 \\ 6 & 6 & 8 & 7 & 6 \\ 4 & 5 & 3 & 8 & 7 \\ 5 & 4 & 4 & 3 & 9 \end{pmatrix}. \tag{10}$$

The values of TQM_{PA_1PI} computed from expressed (4) is given as

$$\begin{aligned} TQM_{PA_iPI} &= A_1 * per\left(PM_{TQM-A_1}\right) \\ &= 8 * 6996748 \\ &= 5597984. \end{aligned} \tag{11}$$

Similarly, other values are computed. The values of TQM_{PA_iPI} for each attribute of all hospitals along with the most influential attribute for the hospital are tabulated in Table 8.

Now, to find in which hospital a particular attribute is implemented more effectively, the percentage contribution of each attribute in the TQM index of every hospital is computed by using expression (5) and tabulated in Table 9.

10. Discussion and Interpretations

One of the findings of our proposed technique of TQM digraph is the ranking of public sector teaching hospitals in Punjab. The results show that Services Hospital in the Lahore

Table 7: TQM performance index of public sector hospitals in Punjab.

Sr. No	Hospitals	TQM_{HPI}
1	JH	19613264
2	SZH	25630328
3	SH	26421690
4	GNSH	24741788
5	LGH	20926136
6	SMH	17635610
7	GMTH	15417654
8	LAH	18344248
9	CHL	23968700
10	LWH	16490026
11	MH	23928594
12	PIOC	21575517
13	SGRH	19478626
14	GMMH	7648760
15	GKKSTH	7307584
16	GTHS	7341906
17	GSBTH	9058589
18	ABSH	8172462
19	DHQHG	13447348
20	WIC	12197292
21	DHQHR	7499652
22	HFH	11643772
23	BBH	6953568
24	RIOC	14350197
25	AH	14368788
26	DHQHF	11827844
27	GGHGMA	10670820
28	FIC	14458944
29	CHF	15995937
30	DHQHS	4327128
31	DHQHS	6873612
32	NH	11045442
33	CPEIOC	12990916
34	CHM	10956831
35	BVH	10601131
36	CACSH	13058376
37	CHB	5813200
38	SZMH	6885166
39	THDGK	4761556

district with the highest value of TQM_{HPI} has the best TQM practices implementation. The top five TQM performance-based hospitals are Services Hospital, Sheikh Zayed Hospital, Government Nawaz Sharif Hospital, Children Hospital, and Mayo Hospital, which are located in Lahore city. Twelve out of 16 teaching hospitals in the Lahore division are ranked from 1 to 12 based on the best TQM practices. Their higher scores in descending order differentiate them in comparison to the other teaching hospitals. The reason behind their good performance might be the impact and focus of healthcare service providing local authorities as well as effective management. The results also indicate that 2 hospitals GTHS and GKKSTH of the Lahore division are ranked among the bottom 10 hospitals with respect to the TQM index, which means these 2 hospitals follow poor TQM practices. The reasons behind the low performance regarding TQM practice might be due to management issues and under-utilization of scarce resources due to their geographical location. Moreover, it is evident from the results that the bottom five hospitals with respect to the TQM index are SZMH, DHQHS, CHB, THDGK, and DHQHS. Geographically, these hospitals are located in those districts that are far from the provincial capital (Lahore) and being neglected by the healthcare authorities that might be the reasons behind their poor TQM performance. The obtained results might be guidance for the government of Punjab to look after the most neglected areas of this province regarding healthcare facilities.

The other finding of this research elaborates the indication of the most influential attribute affecting the TQM practices that can be witnessed in Table 8. It can be seen from Table 8 that continuous improvement is the most influential attribute for Lahore General Hospital, that is, the betterment in this TQM attribute as compared to other attributes will lead to better TQM performance for Lahore General Hospital. Moreover, from Table 7, we can see that value of both CI (A_2) and PS (A_6) for Lahore General Hospital is the same, that is, 9, but CI is more influential than PS. This can be seen in Figure 4.

The similar comparison between the TQM index of attribute and an attribute value of Children Hospital of Faisalabad, Children Hospital of Lahore, and Nishtar hospital of Multan is shown in Figures 5–7, respectively. In all these figures, we can easily see that the values of attributes are not sufficient to indicate that which TQM attribute should be focused on to improve the TQM performance of a hospital. On the other hand, the TQM index, TQM_{A_iPI}, helps identify the attribute that is needed to improve the TQM performance of a hospital. The hospitals located in different communities have been facing different problems so it is not possible for every hospital to incorporate all the TQM attributes efficiently. Healthcare authorities can get benefit from these results of influencing TQM attributes for each hospital in decision-making in order to maximize the performance within the applied resources keeping in view the geographic conditions of poorly performed hospitals with respect to TQM practices. In addition, if the results obtained from this research are applied in true spirit, then it may increase the efficiency of hospitals and healthcare service professionals. The results can also minimize the non-effective resources, and ultimately, it will reduce the potential burden on the healthcare budget.

The third finding of this research indicates that for which hospital, a particular TQM attribute is contributing up to the maximum level in its TQM performance. From Figures 8–13, we can see that top leadership management is effective both in Services Hospital and Government Nawaz Sharif Hospital. Continuous improvement and patient satisfaction have a strong impact on the TQM performance of Services Hospital, whereas the performance management system plays an important role in the TQM performance of Sheikh Zayed Hospital. Employee's empowerment is more effective in Government Nawaz Sharif Hospital, whereas effective operational management is better implemented in Sheikh Zayed Hospital, Services Hospital, Government Nawaz Sharif Hospital, Children Hospital Lahore, and Mayo hospital. These results help the healthcare authorities to apply check

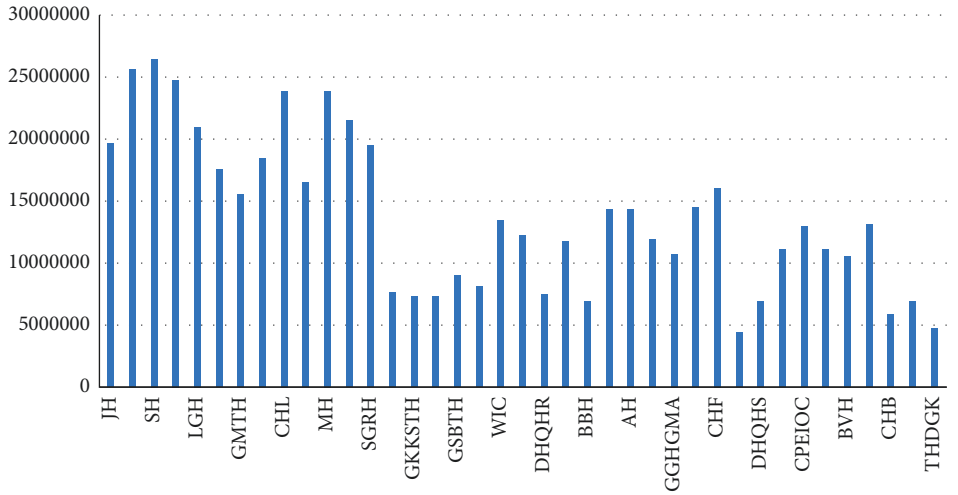

Figure 2: TQM index-based ranking of public sector hospitals in Punjab.

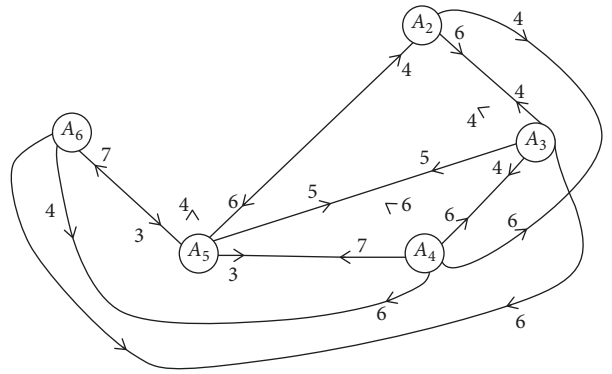

Figure 3: The digraph PM_{TQM-A_1}.

Table 8: TQM performance index of TQM attributes.

Hospitals	TQM_{A_1PI}	TQM_{A_2PI}	TQM_{A_3PI}	TQM_{A_4PI}	TQM_{A_5PI}	TQM_{A_6PI}	IA
JH	5170480	4782680	5263488	5887224	5757048	4621148	EE
SZH	7722144	7819029	8371290	8097552	8471280	7589997	PS
SH	8554490	8656200	7539888	8389458	8792160	8420600	EOM
GNSH	7904880	6938080	6961168	8273140	8120000	7272144	EE
LGH	5597984	6137892	5692032	5892800	5767936	5943348	CI
SMH	4327365	4625040	4634144	4382490	4278064	4833864	PS
GMTH	3148350	3448592	3593282	3338148	3254472	3797184	PS
LAH	4775328	4414004	4862208	5034752	4919040	4262692	EE
CHL	6595992	7216776	7232508	7473204	7820760	6995808	EOM
LWH	3419394	3884048	3889718	3613788	4695084	4118352	EOM
MH	7112250	7201017	7218054	6916840	7812320	6989211	EOM
PIOC	6260805	6794330	5380291	6094808	6898400	5197710	EOM
SGRH	5935590	5618052	5215424	4926810	5279808	4103076	TLM
GMMH	530236	998376	781146	818490	1014648	950784	CI
GKKSTH	0	943648	735780	537776	1153760	1082120	EOM
GTHS	726918	514288	515290	540490	1346376	906720	EOM
GSBTH	1247132	1468490	1473455	1282464	1240912	1164180	PMS
ABSH	860199	1298850	1042040	887406	1095216	800868	CI
DHQHG	3302096	2710512	2363860	2460460	2762616	2933616	TLM
WIC	2375976	2011680	2421108	1833400	2456448	2320464	EOM
DHQHR	1375032	1308018	528422	290292	537280	722709	TLM
HFH	2780376	2557884	1653392	1356672	2015520	2194008	TLM

Table 8: Continued.

Hospitals	TQM_{A_1PI}	TQM_{A_2PI}	TQM_{A_2PI}	TQM_{A_4PI}	TQM_{A_5PI}	TQM_{A_6PI}	IA
BBH	1256592	1196424	480988	0	255792	658320	TLM
RIOC	3870693	2928426	2940522	2661605	2985780	3170006	TLM
AH	3245004	3292177	2559935	2665195	3351649	3497944	PS
DHQHF	2069495	2329368	2334480	2112720	2364624	2231808	EOM
GGHGMA	1461648	1785040	2065152	1560240	1814560	1973064	PMS
FIC	3267992	3319218	2972304	3089640	3013920	3198398	CI
CHF	3692409	3346698	3757460	3898944	3807321	3972144	PS
DHQHS	144053	273376	142796	0	0	0	TLM
DHQHS	698244	0	1060150	718146	889896	649008	PMS
NH	2110278	1859180	1557256	1943850	1893680	2060676	TLM
CPEIOC	2561676	2919742	2263780	1976088	2971248	2813090	CI
CHM	2172546	1769350	1843750	1263396	1875165	2294082	PS
BVH	1737735	2295132	1477580	1212645	1801680	1960098	CI
CACSH	2334280	2521368	2626704	2734608	2660544	2821700	PS
CHB	569640	559776	722432	0	394752	191424	TLM
SZMH	671442	879572	249969	720195	485874	839040	CI
THDGK	161745	442956	0	168280	0	289672	CI

Table 9: Percentage contribution of each attribute in TQM performance of hospitals.

Hospitals	$\%TQM_{A1PI}$	$\%TQM_{A2PI}$	$\%TQM_{A3PI}$	$\%TQM_{A4PI}$	$\%TQM_{A5PI}$	$\%TQM_{A6PI}$
JH	26	24	27	30	29	24
SZH	30	31	33	32	33	30
SH	32	33	29	32	33	32
GNSH	32	28	28	33	33	29
LGH	27	29	27	28	28	28
SMH	25	26	26	25	24	27
GMTH	20	22	23	22	21	25
LAH	26	24	27	27	27	23
CHL	28	30	30	31	33	29
LWH	21	24	24	22	28	25
MH	30	30	30	29	33	29
PIOC	29	31	25	28	32	24
SGRH	30	29	27	25	27	21
GMMH	7	13	10	11	13	12
GKKSTH	0	13	10	7	16	15
GTHS	10	7	7	7	18	12
GSBTH	14	16	16	14	14	13
ABSH	11	16	13	11	13	10
DHQHG	25	20	18	18	21	22
WIC	19	16	20	15	20	19
DHQHR	18	17	7	4	7	10
HFH	24	22	14	12	17	19
BBH	18	17	7	0	4	9
RIOC	27	20	20	19	21	22
AH	23	23	18	19	23	24
DHQHF	17	20	20	18	20	19
GGHGMA	14	17	19	15	17	18
FIC	23	23	21	21	21	22
CHF	23	21	23	24	24	25
DHQHS	3	6	3	0	0	0
DHQHS	10	0	15	10	13	9
NH	19	17	14	18	17	19
CPEIOC	20	22	17	15	23	22
CHM	20	16	17	12	17	21
BVH	16	22	14	11	17	18
CACSH	18	19	20	21	20	22
CHB	10	10	12	0	7	3
SZMH	10	13	4	10	7	12
THDGK	3	9	0	4	0	6

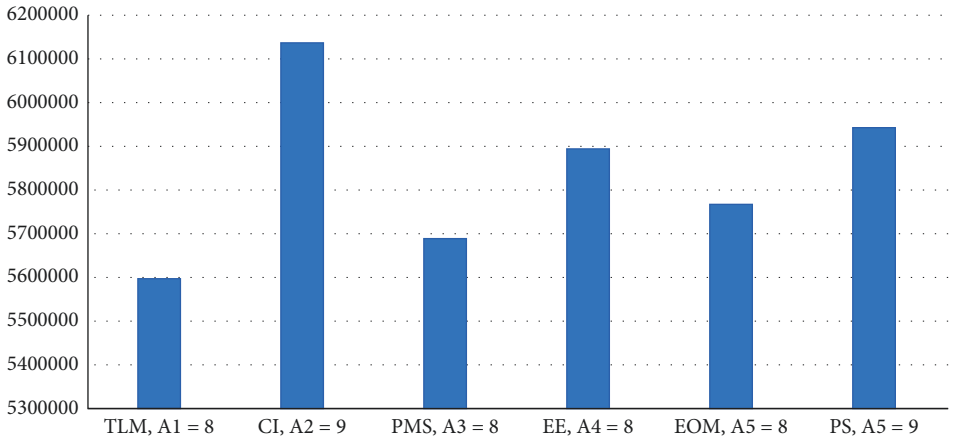

Figure 4: Comparison of TQM index of attribute and attribute value of LGH.

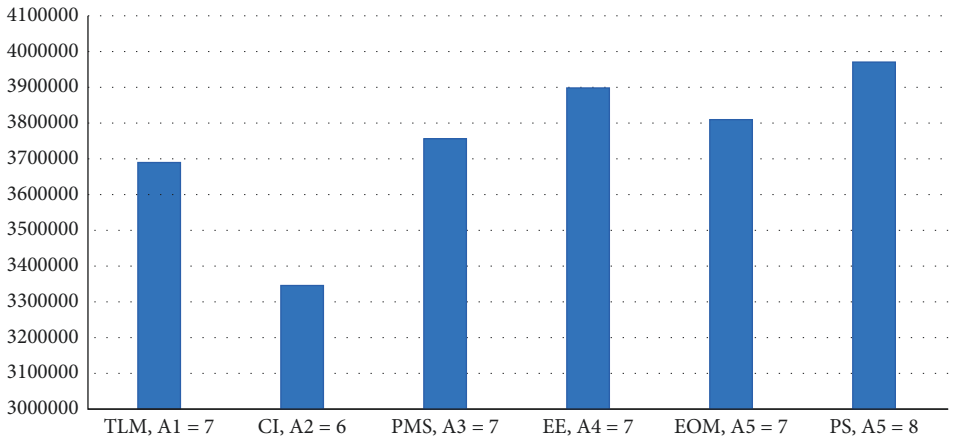

Figure 5: Comparison of TQM index of attribute and attribute value CHF.

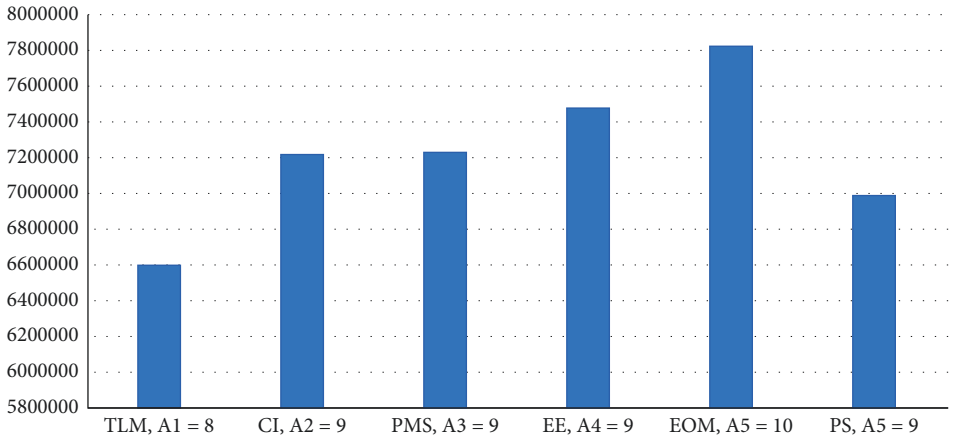

Figure 6: Comparison of TQM index of attribute and attribute value CHL.

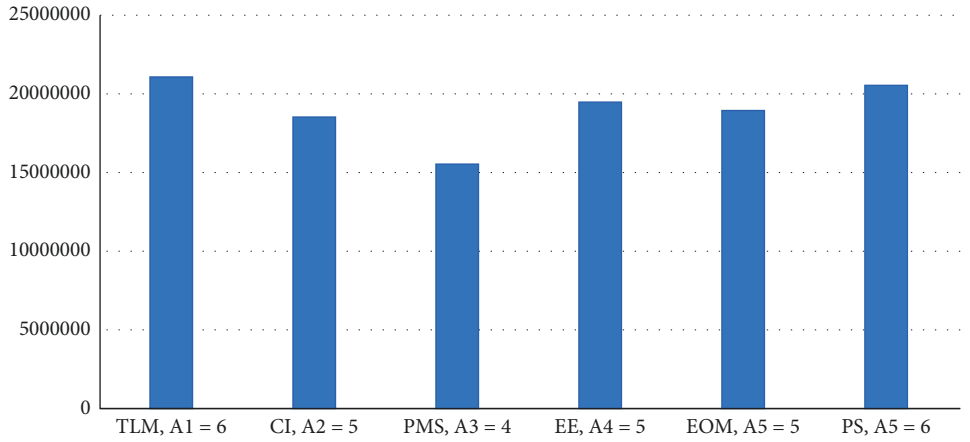

Figure 7: Comparison of TQM index of attribute and attribute value NH.

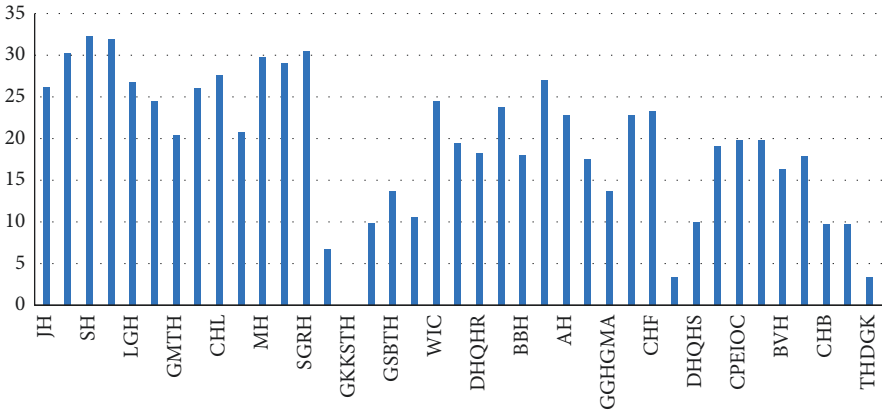

Figure 8: Percentage contribution of TLM in TQM index of the hospital.

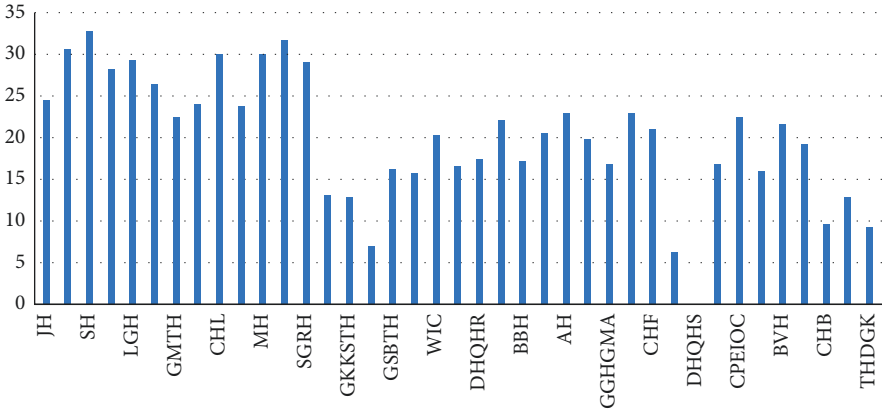

Figure 9: Percentage contribution of CI in TQM index of the hospital.

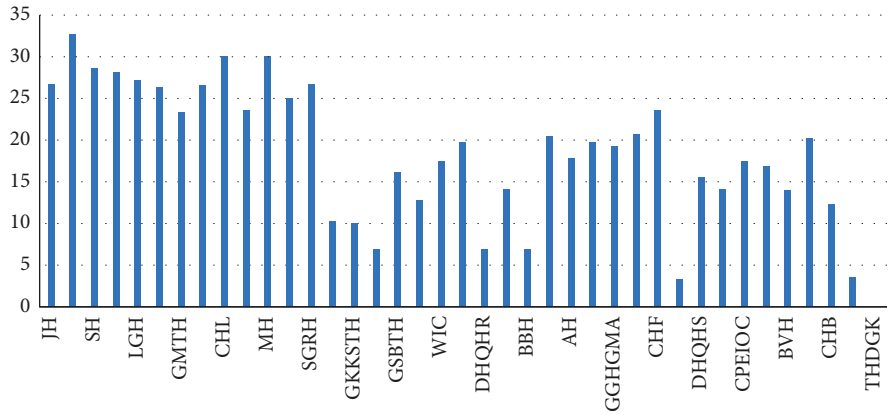

Figure 10: Percentage contribution of PMS in TQM index of the hospital.

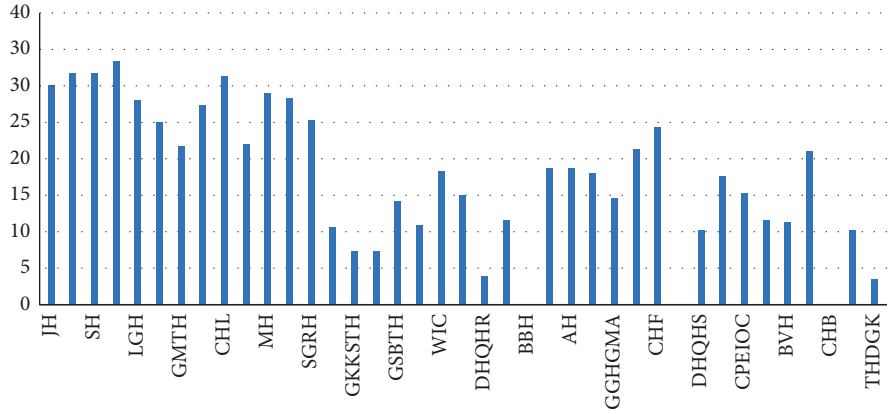

Figure 11: Percentage contribution of EE in TQM index of the hospital.

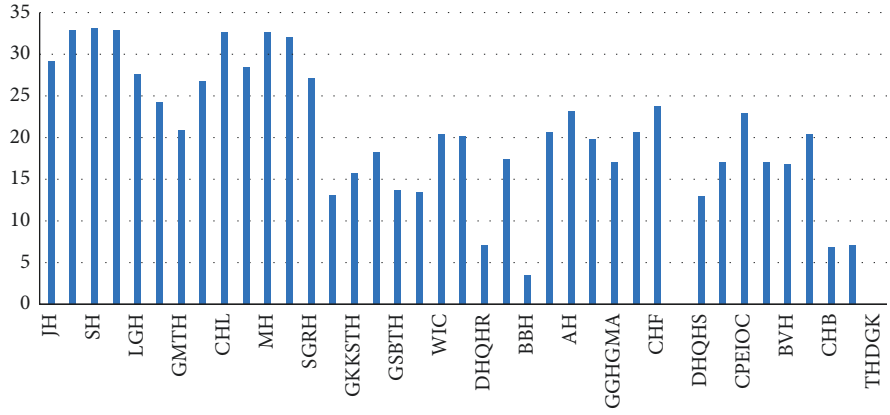

Figure 12: Percentage contribution of EOM in TQM index of the hospital.

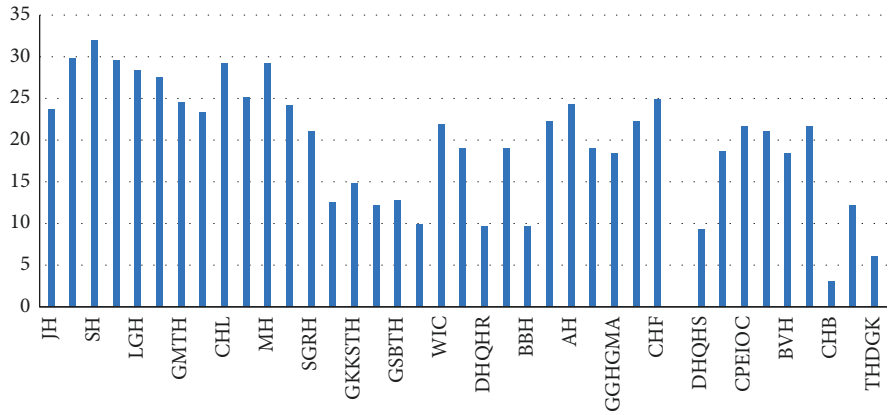

Figure 13: Percentage contribution of PS in TQM index of the hospital.

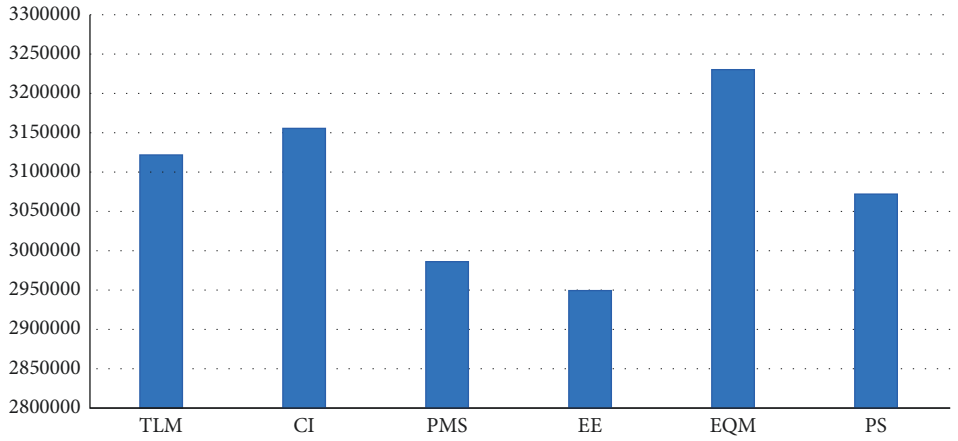

Figure 14: Average contribution of attributes in TQM performance of hospitals.

and balance on the other attributes in TQM performance that are not effectively implemented. In this way, they can give direction to the management to focus on the other attributes and ensure the implementation of these on the same analogy of attributes rightly implemented or triggered.

The average TQM index of all attributes is depicted in Figure 14 that shows that overall in all public sector hospitals in Punjab, effective operational management is implemented in a better way as compared to other attributes.

11. Conclusion

A graph-theoretic technique (GTA) is suggested for analyzing the TQM environment in public sector hospitals in the province Punjab of Pakistan. In the proposed technique, firstly, TQM digraph is constructed for each teaching hospital; then corresponding matrices are obtained; and then using those matrices, the TQM performance index is designed. The hospitals with the highest TQM performance index are considered as the best hospital with reference to TQM implementation. All the hospitals with reference to TQM implementation are ranked. According to the obtained results, Services Hospital has the highest TQM index indicating the best implementation of TQM. The obtained ranking is not only based on the values of all attributes (obtained from the questionnaire) but also on the influencing relations of one attribute over another. This makes this approach more suitable for TQM study in a specific province (Punjab) of Pakistan because the interdependency relations of attributes in different localities may be changed. Secondly, as the hospitals located in different communities have different problems, that is why it is not possible for every hospital to incorporate all the TQM attributes efficiently. The proposed technique settled this problem by providing the procedure to indicate the most influencing TQM attribute for each hospital. This technique not only helps us to evaluate the current TQM performance of hospitals but also helps us to indicate the most effective and influencing attribute for each hospital. The betterment in indicated influencing attribute may lead to a better TQM environment in that hospital. Hence, the results obtained can become the guidelines for health policymakers in Pakistan for better planning and improvements. Furthermore, one can apply this TQM digraph model in wider scope covering the health facilities all over Pakistan instead of one province.

Data Availability

Data used in the study are available on request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] D. E. Bloom, D. Canning, K. Prettner, and J. J. Schünemann, "Health and economic growth: reconciling the micro and macro evidence," *NBER*, 2019.

[2] K. Ratha and P. Lakshmi, "A study on problem faced by patients in private hospitals," *International Journal of Advance Research and Development*, vol. 3, no. 8, pp. 129–136, 2018.

[3] S. Basu, J. Andrews, S. Kishore, R. Panjabi, and D. Stuckler, "Comparative performance of private and public healthcare systems in low- and middle- income countries: a systematic review," *PLoS Medicine*, vol. 9, no. 6, Article ID e1001244, 2012.

[4] S. Mehra, J. Hoffman, and D. Sirias, "TQM as a management strategy for the next millennia," *International Journal of Operations & Production Management*, vol. 21, no. 5/6, pp. 855–826, 2001.

[5] T. Mersha, "TQM implementation in LDCs: driving and restraining forces," *International Journal of Operations & Production Management*, vol. 17, no. 2, pp. 164–183, 1997.

[6] B. G. Dale and C. Cooper, *Total Quality and Human Resources*, Blackwell Publishing, UK, 1993.

[7] A. D. Taveiraa, A. J. Craig, B. Karshc, and F. Sainfortd, "Quality management and the work environment: an empirical investigation in a public sector organization," *Applied Ergonomics*, vol. 34, pp. 281–291, 2003.

[8] P. J. Short and M. A. Rahim, "Total quality management in hospitals," *Total Quality Management*, vol. 6, no. 3, pp. 255–263, 1995.

[9] R. P. Muhhurrum, V. Munhurrum, and A. Panchoo, "Total quality management adaptation in a public hospital: evidence from Mauritius," *Global Journal of Business Research*, vol. 5, pp. 67–77, 2011.

[10] M. Balasubramanian, "Total quality management [TQM] in the healthcare industry – challenges, barriers and implementation developing a framework for TQM implementation in a healthcare setup," *Science Journal of Public Health*, vol. 4, no. 4, pp. 271–278, 2016.

[11] S. Irfan and A. Ijaz, "Comparison of service quality between private and public hospitals: empirical evidences from Pakistan," *Journal of Quality and Technology Management Volume*, vol. 7, no. 1, pp. 1–22, 2011.

[12] S. Irfan and A. Ijaz, "An assessment of service quality of private hospitals in Pakistan: a patient's perspective," *Indian journal of commerce & management studies, (Special Issue)*, vol. 2, no. 2, pp. 20–30, 2011.

[13] S. M. Irfan, A. Ijaz, D. M. H. Kee, and M. Awan, "Improving operational performance of public hospitals in Pakistan: a TQM based approach," *World Applied Sciences Journal*, vol. 19, no. 6, pp. 904–913, 2012.

[14] M. Naseer, A. Zahidie, and B. T. Shaikh, "Determinants of Patient's satisfaction with health care system in Pakistan: a critical review," *Pakistan Journal of Public Health*, vol. 2, no. 2, pp. 56–61, 2012.

[15] F. Talib, Z. Rahman, and M. Qureshi, "The relationship between total quality management and quality performance in the service industry: a Theoretical Model ", International Journal of Business, Management and Social Sciences (IJBMSS)," *MultiCraft*, vol. 1, no. 1, pp. 113–128, 2010.

[16] F. Talib, Z. Rahman, and M. Qureshi, "A study of total quality management and supply chain management practices," *International Journal of Productivity and Performance Management*, vol. 60, no. 3, pp. 268–288, 2011.

[17] M. M. Yasin, J. Alavi, M. Kunt, and T. W. Zimmerer, "TQM practices in service organizations: an exploratory study into the implementation, outcome and effectiveness," *Managing Service Quality*, vol. 14, no. 5, pp. 377–389, 2004.

[18] A. Baykasoglu, "A review and analysis of graph theoretical-matrix permanent approach to decision making with example applications," *Artificial Intelligence Review*, vol. 42, pp. 573–605, 2012.

[19] S. Grover, V. P. Agrawal, and I. A. Khan, "A digraph approach to TQM evaluation of an industry," *International Journal of Production Research*, vol. 42, no. 19, pp. 4031–4053, 2004.

[20] S. Grover, V. P. Agrawal, and I. A. Khan, "Role of human factors in TQM: A Graph Theoretic Approach," *Benchmarking: An International Journal*, vol. 13, no. 4, pp. 447–468, 2006.

[21] S. Kulkarni, "Graph theory and matrix approach for performance evaluation of TQM in Indian industries," *The TQM Magazine*, vol. 17, no. 6, pp. 509–526, 2005.

[22] G. Anand and B. K. Bahinipati, "Measuring horizontal collaboration intensity in supply chain: a graph–theoretic approach," *Production Planning & Control*, vol. 23, pp. 801–816, 2012.

[23] M. Singh, I. A. Khan, S. Grover, and S. C. Gupta, "Assessing quality of manufacturing organizations - a Graph Theoretic Approach," in *Proceedings of the 2011 IEEE International Conference on Industrial Engineering and Engineering Management*, pp. 1740–1744, Singapore, December 2011.

[24] K. Jangra, S. Grover, and F. T. Chan, "Digraph and matrix method to evaluate the machinability of tungsten carbide composite with wire EDM," *International Journal of Advanced Manufacturing Technology*, vol. 56, pp. 959–974, 2011.

[25] K. Jangra and S. Grover, "Digraph and matrix method for the performance evaluation of carbide compacting die manufactured by wire EDM," *International Journal of Advanced Manufacturing Technology*, vol. 54, pp. 579–591, 2011.

[26] H. Jafari and M. Ehsanifar, "Using interval arithmetic for providing a MADM approach," *Journal of Fuzzy Extension and Applications*, vol. 1, pp. 57–65, 2020.

[27] H. Hottenrotha, C. Sutardhiob, A. Weidlichb et al., "Beyond climate change. Multi-attribute decision making for a sustainability assessment of energy system transformation pathways," *Renewable and Sustainable Energy Reviews*, vol. 156, Article ID 111996, 2022.

[28] G. Sirbiladze, "New view of fuzzy aggregations. Part III: extensions of the FPOWA operator in the problem of political management," *Journal of Fuzzy Extension and Applications*, vol. 2, no. 4, pp. 321–333, 2021.

[29] W. M. Lim, M. V. Ciasullo, A. Douglas, and S. Kumar, "Environmental social governance (ESG) and total quality management (TQM): a multi-study metasystematic review," *Total Quality Management*, 2022.

[30] K. Elibal and E. Ozceylan, "Comparing industry 4.0 maturity models in the perspective of TQM principles using Fuzzy MCDM methods," *Technological Forecasting and Social Change*, vol. 175, Article ID 121379, 2022.

[31] S. Siddique, U. Ahmad, and M. Akram, "A decision-making analysis with generalized m-polar fuzzy graphs," *Journal of Multiple-Valued Logic and Soft Computing*, vol. 37, pp. 409–436, 2021.
[32] M. Akram and U. Ahmad, "Complex pythagorean fuzzy threshold graphs with application in petroleum replenishment," *journal of applied mathematics and computing*, 2021.
[33] M. Akram and F. Zafar, "Hybrid soft computing models applied to graph theor," *Studies in Fuzziness and Soft Computing*, Springer, vol. 380, , 2020.
[34] M. Akram and A. Luqman, "Fuzzy Hypergraphs and Related Extensions," *Studies in Fuzziness and Soft Computing*, Springer, Berlin, Germany, 2020.
[35] M. Akram, M. Sarwar, and W. A. Dudek, "Graphs for the analysis of bipolar fuzzy information," *Studies in Fuzziness and Soft Computing*, Springer, vol. 401, , 2021.
[36] R. E. Bellman and L. A. Zadeh, "Decision-making in a fuzzy environment," *Management Science*, vol. 17, no. 4, pp. 141–164, 1970.
[37] P. L. Yu, "A class of solutions for group decision problems," *Management Science*, vol. 19, no. 8, pp. 936–946, 1973.
[38] R. Filppini and C. Forza, "TQM impact on quality conformance and customer satisfaction: a causal model," *International journal of production economics*, vol. 55, pp. 1–20, 1998.
[39] O. U. Ofili, "Patient satisfaction in healthcare delivery a review of current approaches and methods," *European scientific journal, ESJ*, vol. 10, pp. 25–39, 2014.
[40] N. K. Aliman and W. N. Mohamad, "Linking service quality, patient satisfaction, and behavioral intentions: an investigation on private healthcare in Malaysia," *Procedia - Social and Behavioral Sciences*, vol. 224, pp. 141–148, 2016.