# DEVELOPMENT OF A FRAMEWORK FOR EVALUATION OF QUALITY OF EMERGENCY CARE SERVICES OF INDIAN HOSPITALS

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**by**

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## CANDIDATE'S DECLARATION

I Kumar Amit (2K22/IEM/07) hereby certify that the work which is being presented in the thesis entitled "Development of a Framework for Evaluation of Quality of Emergency Care Services of Indian Hospitals" in partial fulfillment of the requirements for the award of the Degree of Master of Technology, submitted in the Department of Mechanical Engineering , Delhi Technological University is an authentic record of my own work carried out during the period from January, 2024 to May 2024 under the supervision of Dr. Girish Kumar.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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# Development of a Framework for Evaluation of Quality of Emergency Care Services of Indian Hospitals

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## ABSTRACT

Healthcare is an important service industry and under its aegis, the emergency healthcare service systems are essential for saving precious lives. It has become an integral part of hospital establishments. Promptness with superior quality is essential for the success of such services. This paper aims to assess the service quality of emergency healthcare departments of hospitals by developing a service quality index based on factors that influence emergency healthcare. Numerous factors impact service quality and these factors consist of various sub-factors. The various factors that affect the service quality of emergency healthcare services are identified through literature and field surveys. A structural methodology involving graph theory and matrix is employed for analyzing the interrelationships among various service quality factors. The directed graph (digraph) is employed to represent the interrelationships among various factors influencing service quality in hospital emergency departments. Each node in the digraph symbolizes a specific quality-influencing factor, and the edges represent the degrees of interrelationships between these. The equivalent matrix derived from the digraph leads to the establishment of an emergency healthcare service quality function, ultimately contributing to the evaluation of the emergency care service quality index (ECSQI). A higher value of the service quality index indicates that the emergency department's organization and functioning are deemed adequate. The adapted methodology can be practically applied to evaluate and compare the service quality of different hospital emergency departments. The insights gained from such assessments can assist emergency department managers in devising effective strategies to enhance service quality and overall patient satisfaction.

Keywords: Emergency Care, Service Quality, Diagraph, Emergency care service quality index (ECSQI)

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# List of Abbreviations

| Abbreviations | Meaning |
|---|---|
| AHP | Analytic Hierarchy process |
| ALS | Advanced Life Support |
| BLS | Basic Life Support |
| CI | Consistency Index |
| CR | Consistency Ratio |
| ECSQI | Emergency Care Service Quality Index |
| ED | Emergency Department |
| EHR | Electronic Health Record |
| EMS | Emergency Medical Services |
| ERP | Enterprise Resource Planning |
| HA | Hospital Ambience |
| HM | Hospital Management and Administration |
| HPC | Healthcare Personnel Competencies |
| ISQIR | Ideal Service Quality Index Ratio |
| IT | Information Technology |
| ITI | Information Technology Integration |
| NCD | Non-Communicable Disease |
| NHM | National Health Mission |
| PG | Post Graduate |
| PPE | Personal Protective Equipment |
| RI | Random Index |
| RTI | Road Traffic Injury |
| SCM | Supply Chain Management |
| SDG | Sustainable Development Goals |
| SEM | Structural Equation Modelling |
| SF | Support Facilities |
| SQF | Service Quality Function |
| SQI | Service Quality Index |
| SQIR | Service Quality Index Ratio |
| SSF | Support System Facilities |
| TPQ | Treatment Process Quality |
| WHA | World Health Assembly |
| WHO | World Health Organisation |

# CHAPTER 1

## INTRODUCTION

Emergency healthcare is defined as the provision of time-sensitive medical interventions that are necessary to prevent death and impairment and for which waiting periods may worsen prognosis or decrease effectiveness of care. There are daily several cases of accidents and emergencies in every part of India (NITI Aayog, 2021). Any nation which desires sustainability in healthcare, the focus on providing timely as well as effective emergency healthcare is of utmost importance. India has made commitment to worldwide initiatives like Sustainable Development Goal 3 (SDG3) and World Health Assembly (WHA) resolutions, and hence understands the importance of effective emergency medical services (EMS) in achieving "well-being for all at all ages" according to Kannan et al. (2020). However, the current scenario portrays a different picture, with the issue associated with events such as road traffic injuries (RTIs) which claim around 1.5 lakh lives yearly (Pal et al., 2019) and non-communicable diseases (NCDs) which account for almost 62% deaths, majority of them requiring emergency medical interventions (Dandona et al., 2017). This prompts us to think about the critical need for evaluation and improvement factors for service quality in the context of Indian emergency healthcare systems. The National Health Mission (NHM) of India aims to "prevent and reduce mortality & morbidity" from a wide range of medical conditions (NITI Aayog, 2021). This goal is congruent to the current global focus on emergency medical care as laid out in the WHA 72 resolution, highlighting its important role in ensuring "timely care for the acutely ill and injured." These initiatives make a strong case for prioritizing, improving and expanding the current level of emergency care systems in India. As emergency healthcare system is also considered as a service process which involves the journey of the patient from his admission in the system till his discharge (Sligo et al., 2017), the evaluation of service quality in these systems becomes a necessity. By conducting evaluation of service quality of the EMS involving identification of the key improvement areas, addressing bottlenecks, and optimizing resource allocation results in improved patient health, reduced waiting times in Hospitals and also enhances the public trust in these systems.

Evaluation of service quality of any service organisation requires a multi-factor approach according to James and James (2020). Factors such as protocols, process completion times, and patient experience surveys provide important insights into the emergency healthcare system's effectiveness. Further, analysis of data from emergency medical services such as ambulance services, hospital emergency departments (EDs), and other public health agencies can offer a comprehensive understanding of the status of resource utilization, demographics of patients, and accessibility of service (NITI Aayog, 2021). However, the data collected needs to be analysed and converted into insights for decision making. This requires proper coordination between different healthcare stakeholders, healthcare policymakers, and academic researchers to find and implement research-based solutions (Dormann et al, 2020). Investment in specific and periodic training programs for EMS staff, timely updating emergency medical protocols, and upgradation of healthcare infrastructure are some of the key areas where improvement efforts should be focused. Additionally, using new technology can play a vital role in upgrading emergency healthcare systems. For example, Telemedicine services can reduce the gap for geographically isolated populations, and the digital platforms can facilitate data collection, analysis, and fast decisions (NITI Aayog, 2021). Further, investment in robust communication systems can ensure coordinated decision making during critical situations in a timely manner.

Finally, the journey towards sustainable healthcare in India depends on the success of its emergency healthcare systems as it is very important in saving critical lives. By doing evaluation of service quality and then implementing its results as evidence-based solutions, enhanced by upgrading technology can pave the way for a safe future where every person has the access to fast, effective and affordable healthcare. This, in itself, will be a very significant and major step towards achieving the goals of SDG3 (United Nations, 2015).

## 1.1 India's Emergency Care System: Current Scenario

Despite being a rapidly developing country, India's emergency healthcare system remains in infant stage, mired with the problems such as fragmentation, resource limitation, and a shortage of trained staff (NITI Aayog, 2021). This leads to delays in providing effective treatment, overall poor patient outcomes, and restricted access to medical care, particularly for vulnerable communities.

Overcoming Challenges and Gaps:

Patient care is negatively impacted by delays and inefficiencies caused by the fragmentation of the emergency healthcare system in India, where pre-hospital services (ambulance services) are run independently from facility-based services (hospitals, EDs). A challenging issue is the acute lack of qualified emergency personnel, including physicians, paramedics, and nurses. The development of academic emergency medicine stream and allied disciplines is lagging behind the nation's needs (NITI Aayog, 2021). Inadequate funding further affects the system, limiting infrastructure development, equipment acquisition, and the implementation of effective solutions (McQuestin & Noguchi, 2020). The absence of comprehensive laws and regulations for emergency healthcare creates a regulatory confusion, stopping the establishment of quality standards and hindering patient safety. Finally, tertiary care hospitals (District level public hospitals), which are expected to provide the highest level of emergency care, often lack trained staff, resulting in ineffective care for critical patients (Kannan et al., 2020).

Building a Stronger Future:

Response times for care can be minimized by investing in state-of-the-art ambulances, training of paramedics, and centralized communication systems for pre-hospital care systems. For example, the toll-free number for ambulance in India can be used to inform nearby Hospitals of the incoming critical patient and his status. Further, to retain talented human resource, it is essential to establish an academic emergency discipline for doctors, provide periodic upgradation training for nurses and paramedics, and ensure competitive pay and benefits. Resource mobilization through funding from government agencies, public-private partnerships, and other mechanisms is a must to ensure the financial sustainability (NITI Aayog, 2021). Ensuring high-quality access to emergency care for everyone requires strengthening the legal environment through the implementation of comprehensive legislation and regulations that have clear provisions for patient rights and quality assurance. This ensures that the right to life enshrined in Article 21 of our constitution is upheld. By addressing these issues and establishing a strong emergency care system, India can create the conditions for a healthy future in which all individuals have access to timely and efficient healthcare. This will play a major role in fulfilling the country's goal of universal access to healthcare.

In order to avoid death and permanent disability, emergency treatment is essential. It requires timely care that become ineffective if postponed. People seek emergency medical care across the globe daily. Everyone who requires emergency medical care should be able to get it quickly, and in proper way in order to ensure quality of services. However, a plethora of false beliefs by policymakers cause emergency treatment to be given less importance, especially in low- and middle-income nations. These include comparing emergency medical services only to ambulance services. So, the focus on facility-based care is reduced. Another widespread misconception is that emergency healthcare is always costly and needs high-tech solutions rather than simple and efficient management plans. Thus, improvement of emergency care services does not always mean increased spending. It is actually the main entry point into the healthcare system for a large number of individuals globally, which makes it essential for attaining universal health coverage. According to a 2002 study by researchers, injuries and trauma alone accounted for almost 14% of adult disease cases, highlighting the difficulty of defining the overall burden addressed by emergency medical systems. According to NITI Aayog. (2021), these systems can manage a large variety of medical conditions, including accidents, noncommunicable diseases, obstetrics, and infections. Individuals suffering from these ailments may present themselves at several phases: either as acute symptoms (stroke, acute bleeding, traumas, heart attack) or as naturally acute conditions (diabetes hypoglycemia, premature labor, asthma). According to a recent study, there is a chance that any of the top 15 causes of mortality and disability-adjusted life years could manifest itself as emergency situation. Ensuring quick access to healthcare and early diagnosis of acute medical conditions results in emergency care systems saving lives and improve the effectiveness of other healthcare components. As per the World Bank Disease Control Priorities Project, a properly managed emergency care system has the potential to tackle more than 50% cases of fatalities and 33% cases of disabilities in low-income and middle-income countries.

India has to deal with two types of emergencies: those involving contagious diseases and those involving trauma. Example of trauma is road accident injury and contagious disease is Diabetes related complications. As the pre-hospital care system is underdeveloped mainly due to shortage of qualified staff and equipment in ambulances. The system is disjointed and inadequately integrated with hospitals as discussed earlier, and there is no nationwide emergency number due to health being a state subject. This situation is comparable to that of the United States in the 1960s, when majority of the deaths were caused by delays in emergency care. India's focus on economic growth has resulted in a disproportionately less health budget, despite constitutional provisions protecting the fundamental right to life and medical treatment given in article 21. An estimated 30,000 deaths from snakebite occur each year which makes India having the highest snakebite fatality rate worldwide. Thus, the importance of emergency healthcare for Indian context has been established.

To illustrate their Emergency Care System Framework, the World Health Organization (WHO) created two infographics (Figures 1.1 and 1.2) (World Health Organization, 2017). This framework helps national emergency care systems' policymakers assess and improve their countries’ healthcare systems. It was developed via discussions with national decision-makers and emergency medical professionals across the globe. It provides a point of reference for determining planning and funding strategies, evaluating healthcare system capabilities, and developing monitoring and assessment plans. The basic components of an ideal emergency healthcare system are shown graphically in Figure 1.1, together with the information technology, equipment, and human resources needed to carry them out (categorized according to health systems building blocks). This is supplemented by Figure 1.2, which focusses on governance aspect of the framework, such as necessary protocols, process of certification and accreditation, and key process indicators.

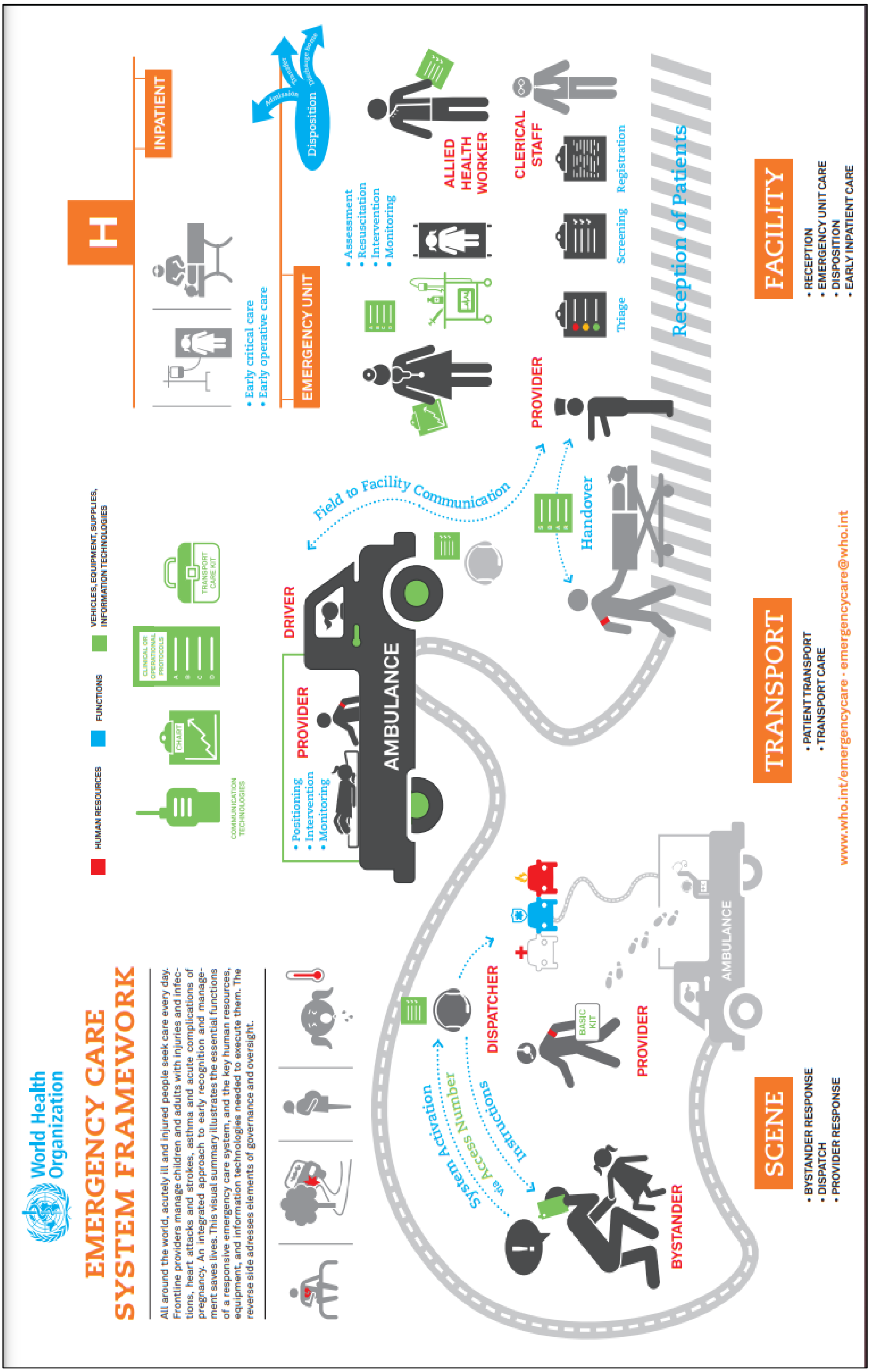


**Fig. 1.1** WHO Emergency System Framework-1

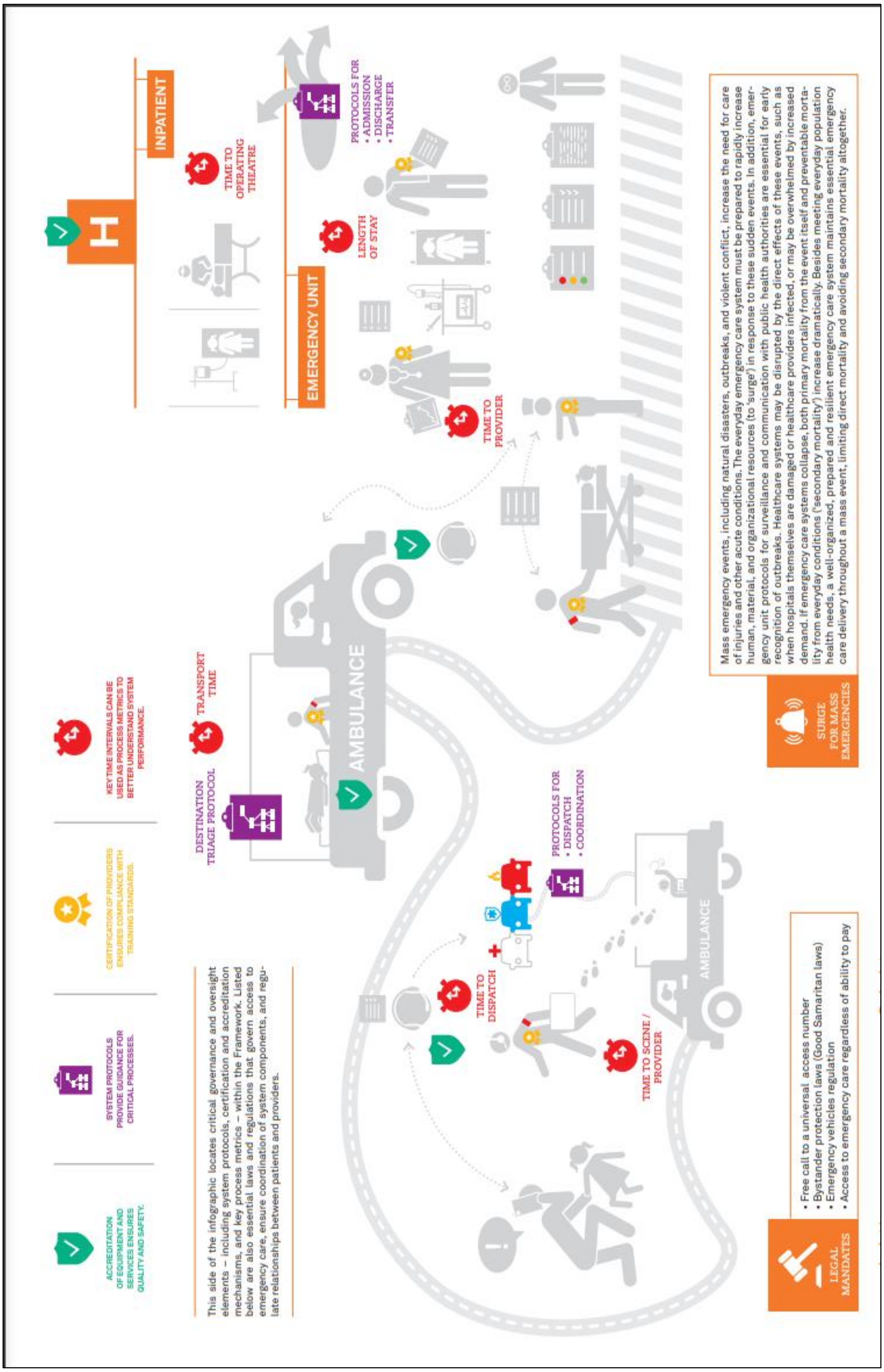


**Fig. 1.2** WHO Emergency System Framework-2

### 1.2 The Need for Service Quality Evaluation in Emergency Care Systems:

As discussed in detail in the previous section, provision for systematic emergency care is essential for maintaining public health and saving lives. The quality of the services these systems provide has a major impact on the effectiveness of public health strategies. Assessing the quality of services is crucial for multiple reasons:

**Better Results for Patients:**

- **Early intervention:** Patients' care is greatly impacted by quick and efficient emergency care. By identifying areas for improvement, service quality evaluation enables systems to ensure early intervention and address delays quickly, which may enhance patient outcomes.

- **Error reduction:** By identifying deficiencies, service quality evaluations can result in improved practices and a decrease in medical errors, thereby saving precious lives.

- **Better resource allocation:** Resources would be distributed optimally to address urgent needs.

**A higher level of patient satisfaction**

- **Better communication:** Assessments can identify areas in which patient-doctor-staff communications need to be improved, resulting in better treatment and trust building.
- **Shorter wait times:** Well-designed workflows leads to shorter wait times which is a result of quality evaluation and finding out areas to improve.

- **Enhanced accessibility:** Evaluations enable healthcare systems to take appropriate action and guarantee that everyone has fair access to emergency treatment by identifying obstacles to care.

**Increasing System Effectiveness:**

- **Identification of bottlenecks:** Evaluations pinpoint areas where the emergency care process is inefficient, which makes it possible to put measures in place that will speed up the process and cut down on wait times.

- **Data-driven decision-making:** Assessments offer information that may be utilized to take informed decisions regarding the policy modifications, and service delivery, all of which will increase the efficiency of the system.

**Accountability and transparency:**

- **Public trust:** Consistent evaluations of service quality show a dedication to accountability and openness, fostering public confidence in the emergency care system.

- **Benchmarking and comparison:** Performance can be compared to other systems, best practices can be found, and ongoing improvement initiatives can be supported by evaluations.

- **Finding best practices:** By disseminating best practices discovered during assessments, various emergency care systems can enhance the quality of their services, resulting in a generalization and advancement of the industry.

This highlights the need to evaluate and improve service quality in context of Indian emergency care systems. Hence, it would be desirable to build models that quantify service quality. This project seeks to quantify the service quality of emergency healthcare services in hospitals within India. By conducting evaluation of service quality of the EMS involving identification of the key improvement areas, addressing bottlenecks, and optimizing resource allocation results in improved patient health, reduced waiting times in Hospitals and also enhances the public trust in these systems.

Researchers have implemented many approaches for assessing service quality. The SERVQUAL model created by Parasuraman et al. (1988) is one of the important and generic models. This technique assesses service quality by statistical analysis of survey responses from customers. The customer survey questionnaire is based on the five service quality aspects such as tangibles, dependability, responsiveness, assurance, and empathy. Brady and Cronin (2001) proposed another model for evaluating service quality that included three factors: the client-staff relationship, the extent of physical infrastructure, and the attainment level of facilities about customer expectations. These approaches rely heavily on customer feedback and the many elements of service quality, which are then statistically analysed. Though procedures are proven and successful, issues in obtaining actual consumer feedback and flaws in assessment processes will have a detrimental impact on the outcomes.

This project introduces a methodology for the evaluation of service quality using graph theory and matrix techniques as given in James and James (2020). Unlike traditional statistical techniques, this method entails a group of professionals evaluating the service scenario in-person and modelling the results. By using this strategy, statistical estimates are not required and the probability of errors is reduced. It also takes into account circumstances in which the service industry in consideration might not be able to be adequately assessed in each of the five SERVQUAL model dimensions. The digraph methodology offers flexibility in the evaluation process by allowing the identification of dimensions unique to the particular service sector.

To conclude, service quality assessment is essential to making sure emergency medical systems run efficiently and provide patients with the utmost medical care. A strong and robust emergency healthcare system that serves the community is created majorly by frequent service quality evaluations, which also highlight areas for improvement, improve patient satisfaction, increase system efficiency, and enforce accountability.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Identification of emergency healthcare service quality factors

Emergency care systems are subject to diverse situational and environmental factors that demand a unique approach to their administration. Recognizing the need to identify factors influencing service quality in emergency healthcare, a detailed literature review was undertaken to identify elements that impact service quality within this critical domain of healthcare. This will be very helpful for establishing the relationships among these factors and their modeling for quantification of service quality of emergency care service. Each identified service quality factor also has many subfactors affecting it.

**Table 2.1**: Literature summary of factors influencing the Hospital Emergency Department Service Quality

| S. No | Author(s) | Identified Factors |
|---|---|---|
| 1 | Kannan et al. (2020) | Governance and Financing, Emergency Care Data and Quality Improvement, Scene Care, Transport facility and Patient Transfer, Facility-Based Care and Emergency Preparedness. |

continued on page 14

Table 2.1 (continued)

| S. No | Author(s) | Identified Factors |
|---|---|---|
| 2 | Sørup et al. (2013) | Safety, Patient Centered approach, Patient Satisfaction, employee profile, Work environment, Operations management, Capacity Utilization, Time taken for services, Radiology diagnostic facilities, Laboratory facilities. |
| 3. | Moresky et al. (2019) | Work culture/community, infrastructure, communication/coordination, transport, equipment and personnel, Formal Triage System. |
| 4 | Vergis et al. (2019) | Emergency operative service, Critical care service, and Specialized care service. |
| 5 | Wankhade (2012) | Availability of ambulance in hospital (102/108 services, Advance Life Support, Basic Life Support), Pre-Hospital Notification, Trained Paramedics. |
| 6 | Ebben et al. (2018) | ED protocols, Emergency Manual, Policy on Handling Death Cases, Triage Policy in ED. |
| 7 | Schoenfisch and Pompeii (2016) Salleh et al. (2020) | Measures for Ensuring Safety & Security, Fire Safety, Building Safety, etc. |

continued on page 15

Table 2.1 (continued)

| S. No | Author(s) | Identified Factors |
|---|---|---|
| 8 | Hegazy et al. (2016) | Disaster Management Plan, Disease Management Outbreak Plan, Surge Capacity, Separate Decontamination Area at ED entrance. |
| 9 | Cohen et al. (2008) | Dedicated Staff for gap identification & loop closure, Death Review Committee, quality council, etc. |
| 10 | Dormann et al. (2020) | Computerized Data Management System, Electronic Health Record, Patient Registration System, etc. |
| 11 | Mcquestin and Noguchi (2020) | Central/State Govt. Funds for ED Services |
| 12 | Liu et al. (2014) | Physical Infrastructure, Linkage to other facilities on same floor, Names of doctors and staff are displayed, Separate room for sexual Assault victim, Important telephone numbers are displayed. |
| 13 | Wrede et al. (2020) | Availability of experienced consultants, doctors, nurses, and paramedics specialize in rapid response and acute care. |
| 14 | Okeagu et al. (2021) | Essential equipment and supplies, dedicated staff for maintenance of equipment, etc. |

continued on page 16

Table 2.1 (continued)

| S. No | Author(s) | Identified Factors |
|---|---|---|
| 15 | Rashsepar et al. (2022) | Point of Care Labs |
| 16 | Cloutier et al. (2020) | 24x7 presence of resuscitation medicines, other essential medicines |
| 17 | Pease et al. (2019) | Communication skills of people in the emergency care unit. |
| 18 | Hemadeh et al. (2018) | Patient information display system, grief counselling |
| 19 | Kumari et al. (2022) | Anti-violence mitigation policy |
| 20 | Bhatia et al. (2016) | 24x7 Blood bank in-house |
| 21 | Forster et al. (2003) | Bed availability mechanism for ED overcrowding. |

## 2.2 Outcome of literature review

It can be summarized from the Exhaustive Literature review that: -

Several of the factors are similar in the findings of various papers. Accordingly, these factors can be grouped into seven major factors such as

1. Hospital Management and Administration (HM),
2. Healthcare Personnel Competencies (HPC),
3. Support facilities (SF),
4. Pre-Hospital and Hospital ambience (HA),
5. Supply chain management (SCM),
6. Treatment process quality (TPQ).
7. Information Technology Integration (ITI)

These will form the major factors on which the service quality of ED depends and our project focus will be on these. The many subfactors of these 7 major factors are elaborated in next section.

### 2.2.1 Hospital Management and Administration:

The delivery of superior emergency care is contingent upon the presence of Hospital Management (HM). A competent medical team is built on the hiring, educating, and tactical placement of medical professionals, such as physicians, paramedics, and support personnel (Mahdavi et al., 2023). While rotational assignments for medical staff and nursing students from various disciplines contribute to a holistic approach in the Emergency Department (ED), efficiently scheduling consultants and faculty ensures a skilled and balanced workforce (Güler & Geçici, 2020). Specific responsibilities assigned to physicians, nurses, and paramedics encourage specialization and improve cooperative teamwork (Spaulding et al., 2021). According to Abid et al. (2023), a responsive healthcare system is ensured by ways such as surveys, continuous improvement initiatives, and the systematic collection of patient input. Prioritizing patient requirements can be facilitated by implementing a TRIAGE system, and maintaining hospital resources and assuring long-term operational performance require strategic financial management (Worth et al., 2019). Thus, the following is an inventory of the subfactors.

1. Recruitment, training and deployment of healthcare professionals (doctors and paramedics, staff, etc.)
2. Efficient Scheduling of Consultants/Faculty posting in emergency department.
3. Rotation of medical personnel and nursing students from different disciplines in ED.
4. Dedicated post of doctors, nurses and paramedics for emergency department
5. Feedback collection from patients, surveys, and continuous improvement
6. Implementation of TRIAGE system for effective patient prioritization.
7. Strategic Financial Management

### 2.2.2 Healthcare Personnel Competencies (HPC):

Healthcare Personnel Competencies (HPC) are paramount in delivering quality emergency care. Proficient communication skills, cognitive adaptability, multitasking capacity, continuous education, and prioritizing physical well-being collectively contribute to a resilient and highly skilled healthcare workforce. The effective collaboration of diverse capabilities ensures comprehensive patient care and a dynamic response to the fast-paced and unpredictable nature of emergencies (Sonis et al., 2017). Emergency care relies heavily on skilled and resilient human resources. Effective teams require diverse expertise, from physicians and nurses to technicians and support staff. Continuously investing in training, fostering a collaborative environment, and promoting mental well-being is crucial for building a strong and adaptable workforce capable of delivering high-quality care in fast-paced, stressful situations. So, the subfactors can be enumerated as follows:

1. Communication Skills of Staff: Patient Engagement, Grief Counselling, Empathy, Shared Decision making
2. Cognitive Skills
3. Multitasking Capacity
4. Continuous Education and training

### 2.2.3 **Support Facilities (SF)**:

The support system facilities (SSF) factor plays a pivotal role in ensuring the seamless functioning and effectiveness of a hospital emergency department (ED). This factor encompasses various critical aspects that contribute to the overall quality of patient care. First and foremost, the availability of ED manuals and protocols ensures that healthcare providers adhere to standardized procedures, enhancing the consistency and reliability of emergency services (Mostafa & El-Atawi, 2024). Routine inspection of ED equipment is crucial for maintaining operational readiness and preventing potential failures during critical situations. The availability of essential medicines is paramount for swift and effective intervention, allowing healthcare professionals to respond promptly to diverse medical emergencies (Hunie et al., 2020). Safety plans within the hospital, including the implementation of Point of Care Labs and 24x7 in-house blood bank services, contribute to a secure and well-equipped environment for patient care (NITI Aayog, 2021). Addressing these subfactors collectively ensures that the Support System Facilities in the emergency department are optimized, fostering a conducive setting for delivering high-quality and timely healthcare services. So, the subfactors can be enumerated as follows:

1. Availability of ED manuals, protocols, etc.
2. Routine Inspection of ED equipment
3. Availability of Essential Medicines
4. Safety Plans in Hospital
5. Point of Care Labs
6. Blood bank services 24x7 inhouse

### 2.2.4 **Pre-Hospital ambience and Hospital ambience**:

The Pre-Hospital and Hospital Ambience factor plays a pivotal role in shaping the overall patient experience and the effectiveness of emergency care services. It encompasses a range of elements aimed at optimizing the environment both before and within the hospital. Access to simple, integrated, and toll-free phone numbers for ambulances ensures swift response and timely initiation of emergency services as per Wankhade (2012). The presence of a 24x7 in-house ambulance equipped with Advanced Life Support (ALS) and Basic Life Support (BLS) staff, along with strategic partnerships with third-party ambulances, enhances the accessibility and efficiency of pre-hospital care (Sanghavi et al., 2015). Pre-hospital notification systems further facilitate seamless transitions, allowing the emergency department (ED) to prepare adequately for incoming cases (Wankhade, 2012). Ensuring easy and direct access to the ED, provision of Personal Protective Equipment (PPE) and safety gear, and meticulous planning for beds, buffer beds, and emergency operative surgeries contribute to creating a safe and supportive hospital ambiance (NITI Aayog, 2021). Maintaining a high standard of cleanliness within the emergency department is crucial for infection control and patient well-being. Routine inspection of equipment, adherence to safety plans, and the availability of essential medicines contribute to a sterile and secure environment (Mostafa & El-Atawi, 2024). Additionally, ensuring adequate lighting in the emergency department is essential for accurate diagnostics and efficient workflow, promoting a safe and well-lit space for both healthcare providers and patients as per Mehrotra et al. (2015). The establishment of an independent Emergency Department and the implementation of public outreach programs further contribute to a comprehensive approach, enhancing the overall quality of care and accessibility in emergencies (NITI Aayog, 2021). So, the subfactors can be enumerated as follows:

1. Access to simple, integrated and free phone numbers for Ambulance
2. 24x7 inhouse ambulance with ALS and BLS and trained staff
3. Tie-up with third party ambulance
4. Pre-Hospital Notification
5. Easy and direct access to ED
6. Provision of PPE and safety equipment
7. Availability of beds, buffer beds planning, emergency operative surgeries
8. Cleanliness
9. Lighting

### 2.2.5 Supply chain management:

The supply chain management factor is instrumental in optimizing the operational efficiency of emergency departments which ensures the seamless flow of resources for effective patient care. Inventory management systems availability facilitates the timely tracking and restocking of essential supplies, minimizing the risk of shortages as per Okeagu et al. (2021). Careful selection of equipment and medicine suppliers ensures a reliable source of high-quality resources, contributing to the overall reliability of emergency care services (Hou et al., 2022). Efficient waste management further enhances the sustainability and cleanliness of the department (Zhao et al., 2022). By effectively managing the supply chain, emergency departments can not only improve patient care but also achieve cost savings and operational excellence, ultimately enhancing the overall quality and success of healthcare delivery. So, the subfactors can be enumerated as follows:

1. Inventory Management Systems availability
2. Equipment supplier selection
3. Medicine Supplier Selection
4. Waste Management availability

### 2.2.6 Treatment process quality

The treatment process quality factor is paramount in determining the effectiveness of emergency care services. Dedicated staff for gap identification ensures a proactive approach to addressing any shortcomings in the treatment process, fostering a culture of continuous improvement (NITI Aayog, 2021). Diagnostic accuracy stands as a critical subfactor, emphasizing the precision and reliability of medical assessments crucial for informed decision-making (Moeller et al., 2008). Monitoring and mitigating the occurrence of treatment or medication errors through rigorous protocols and vigilant staff contribute to patient safety (Mieiro et al., 2019). The establishment of a Death Review Committee enables thorough analyses of adverse outcomes, promoting learning and preventing future incidents (Khader et al., 2021). Standardized treatment processes streamline care delivery, ensuring consistency and adherence to best practices. In conclusion, this factor underscores the multidimensional efforts required to ensure treatment process quality in emergency departments, with an emphasis on precision, safety, and continual improvement.

So, the subfactors can be enumerated as follows:

1. Dedicated Staff for gap identification
2. Diagnostic Accuracy
3. Occurrence of Treatment/medication errors
4. Death Review Committee
5. Standardized Treatment Process

By investing in skilled staff, advanced technology, effective protocols, and continuous improvement initiatives, EDs can deliver timely, efficient, and life-saving care to patients in need.

### 2.2.7 **Information Technology Integration**:

Information Technology Integration in modern healthcare enables the seamless integration of various technological systems in order to enhance system efficiency and improve service quality as per Handel et al. (2011). Enterprise resource planning (ERP) system presence in the Hospital ensures a synchronized workflow by managing financials, human resources, and the supply chain (Van Merode et al., 2004). The electronic health record (EHR) system enables the digitalization of patient health information, facilitating comprehensive and accessible care. The electronic patient registration system streamlines quick admissions through faster data management, reducing paperwork and errors as per Shahmoradi et al. (2017). The ED Surveillance System helps in real-time monitoring of emergency department processes, improving patient flow. Additionally, the data retrieval system ensures swift access to critical information, empowering healthcare professionals with timely and accurate data for informed decision-making (Mostafa & El-Atawi, 2024).

So, the subfactors can be enumerated as follows:

1. ERP system availability
2. Electronic Health Record
3. Patient Registration System
4. ED Surveillance System,
5. Data Retrieval System

Collectively, these subfactors under information technology integration play a crucial role in advancing healthcare delivery, fostering connectivity, data accuracy, and operational efficiency.

Table 2.2 illustrates all the identified factors and their respective sub-factors along with their notations. Figure 2.1 depicts the hierarchy diagram for the factors and their respective sub-factors.

**Table 2.2:** Identified Service quality factors and their respective sub-factors.

| **Factors** | **Subfactors** | **Notation** |
|---|---|---|
| Hospital Management and Administration (HM) | Recruitment, training, and deployment of healthcare professionals | $HM_1$ |
| | Efficient Scheduling of Consultants/Faculty posting in the emergency department. | $HM_2$ |
| | Rotation of medical personnel and nursing students from different disciplines in the ED | $HM_3$ |
| | Dedicated post of doctors, nurses, and paramedics for the emergency department | $HM_4$ |
| | Feedback collection from patients, surveys, and continuous improvement | $HM_5$ |
| | Implementation of the TRIAGE system for effective patient prioritization. | $HM_6$ |
| | Strategic Financial Management | $HM_7$ |
| Healthcare Personnel Competencies (HPC) | Communication Skills of staff, including grief counselling | $HPC_1$ |
| | Cognitive Skills | $HPC_2$ |
| | Multitasking Capacity | $HPC_3$ |
| | Continuous Education and training | $HPC_4$ |
| Support Facilities (SF) | Availability of ED manuals, protocols, etc | $SF_1$ |
| | Routine Inspection of ED equipment | $SF_2$ |
| | Availability of Essential Medicines | $SF_3$ |
| | Safety Plans in Hospital | $SF_4$ |
| | Point of Care Labs | $SF_5$ |
| | Blood bank services 24x7 in-house | $SF_6$ |
| Pre-Hospital and Hospital Ambience (HA) | Access to simple, integrated, and free phone numbers for Ambulance | $HA_1$ |
| | 24x7 in-house ambulance with ALS and BLS and trained staff | $HA_2$ |
| | Tie-up with third-party ambulance | $HA_3$ |
| | Pre-Hospital Notification | $HA_4$ |
| | Easy and direct access to ED | $HA_5$ |
| | Provision of PPE and safety equipment | $HA_6$ |
| | Availability of beds, buffer beds planning, emergency operative surgeries | $HA_7$ |
| | Cleanliness | $HA_8$ |
| | Lighting | $HA_9$ |
| Supply Chain Management (SCM) | Inventory Management Systems availability | $SCM_1$ |
| | Equipment supplier availability | $SCM_2$ |
| | Medicine Supplier availability | $SCM_3$ |
| | Waste Management availability | $SCM_4$ |

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Table 2.2 (continued)

| **Factors** | **Subfactors** | **Notation** |
|---|---|---|
| Treatment Process Quality (TPQ) | Dedicated Staff availability | $TPQ_1$ |
| | Diagnostic Accuracy | $TPQ_2$ |
| | Occurrence of Treatment/medication errors | $TPQ_3$ |
| | The existence of the death review committee | $TPQ_4$ |
| | Standardized treatment process | $TPQ_5$ |
| Information Technology Integration (ITI) | Enterprise resource planning (ERP) system availability | $ITI_1$ |
| | Electronic Health Record | $ITI_2$ |
| | Patient Registration System | $ITI_3$ |
| | ED Surveillance System | $ITI_4$ |
| | Data Retrieval System | $ITI_5$ |

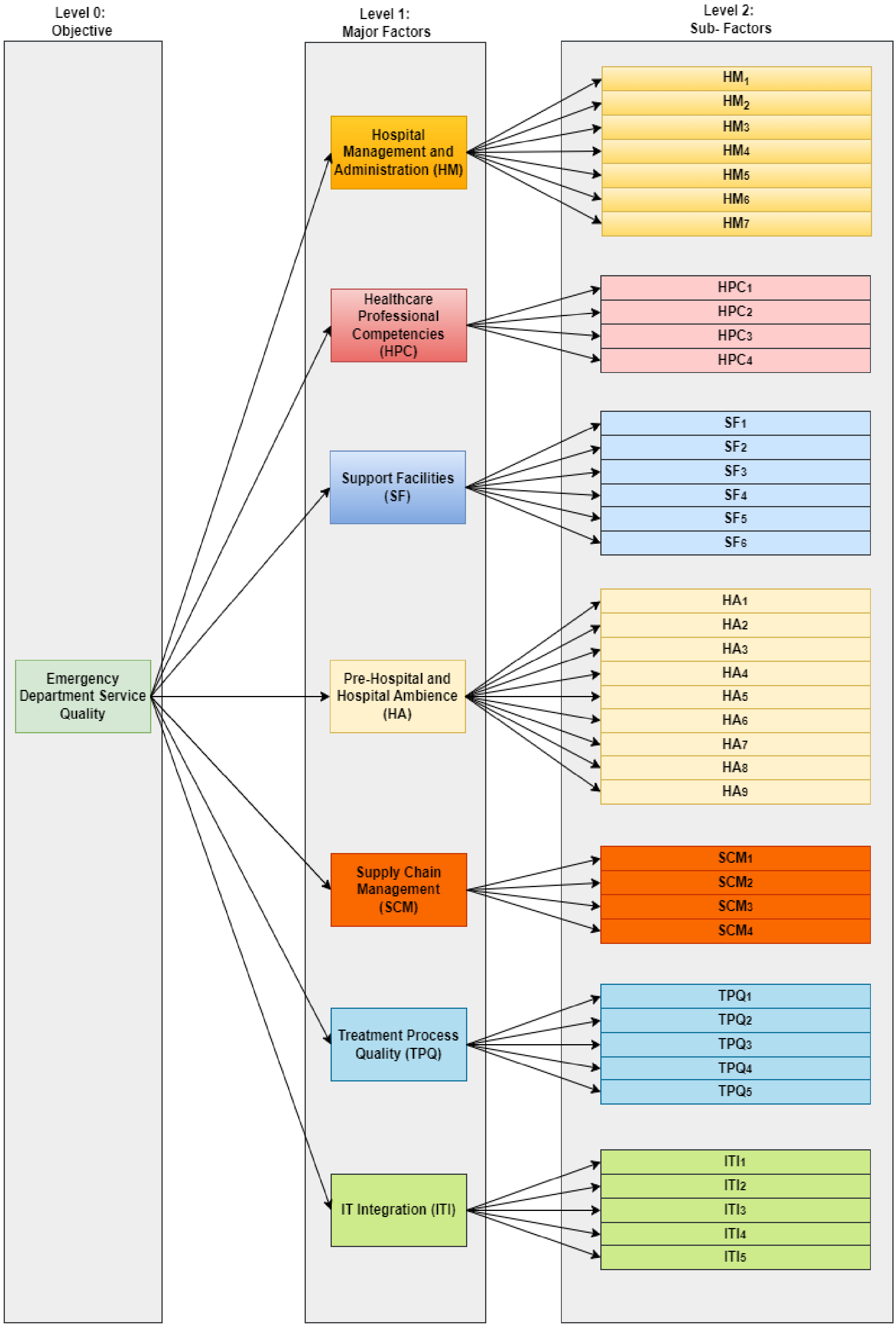


**Fig. 2.1.** Hierarchy diagram of the identified factors and sub-factors.

## 2.3 Research gap

After the exhaustive review of the literature, the following research gaps were identified:

1. Despite enormous studies on the ED Service quality factors from various dimensions, the development of a service quality index (SQI) based on these factors for Emergency care systems has been less explored.
2. The various interrelationships among these factors are to be studied.
3. Traditional service quality evaluation methods such as SERVQUAL (Parasuraman et al., 1988) rely heavily on customer surveys (based on the criteria of tangibles, reliability, responsiveness, assurance and empathy) and statistical analysis. These methods are susceptible to bias and errors. Additionally, there are problems associated with extracting proper feedback from customers and also the errors while doing assessment jeopardizes the results.
4. In the studied literature, there is lack of using Structural Equation Modelling (SEM) using Directed graph for service quality evaluation for Emergency service sector.

## 2.4 Research Objective

1. Identify Service quality factors influencing Emergency Case Systems.
2. Develop Interrelationship between these factors
3. To evaluate the service quality of Emergency Care Systems through development of a service quality index (SQI) based on the identified factors influencing it.
4. To apply Graph theory and matrix approach for the development of SQI.

# CHAPTER 3

## METHODOLOGY

Service quality modelling for the emergency department of a hospital necessitates a thorough consideration of factors influencing service quality and their mutual dependence on each other. In Chapter 2, these factors and associated sub-factors were identified by literature survey and now their structural interrelations can be modelled using a graph theory method, as illustrated by James and James (2020). Digraph models, with directional arrows are well-suited for analysing the various relationships within the system, providing a robust methodology for the evaluation of service quality in the context of any service industry. This study uses this methodology to create a directed graph, or digraph, in which the nodes represent the factors that influence service quality and the edges represent the mutual relationships between these factors.

A directed graph is a structure comprising of distinct nodes or vertices linked by directed edges or arcs. Each node in the graph represents distinct system variables, states, or factors pertinent to the hospital emergency services. Meanwhile, the directed edges symbolize the dynamic relationships and influences among these elements. This graphically depicts the intricate system structure within the emergency department, capturing the interplay of various factors that contribute to the overall service quality. Extending this concept, the digraph model becomes a valuable tool for comprehensively modelling and assessing service quality within the hospital emergency service context.

The emergency system service quality directed graph is defined as $G_d$ = (F, R), in which F represents a set of nodes {$F_1$, $F_2$, $F_3$,… $F_N$}, and R represents a set of edges {$r_{ij}$, ..., $r_{NN}$}, with i and j ranging from 1 to N. Nodes, such as $F_1$, denote specific service quality factors, whereas edges, for instance, $r_{12}$, illustrate the influence of one factor over another. Seven factors, as found from the literature survey, are represented as nodes in our service quality directed graph. This is illustrated in Figure 3.1.

For example, in the hospital emergency department, the Hospital Management (HM) factor plays an important role, having an influence over other six quality factors. The hiring of skilled medical personnel is under the purview of hospital management, creating a direct link between nodes 1 (Hospital Management) and 2 (Healthcare Personnel Competencies). Management responsibilities extend to ensuring a conducive ambience, including factors such as space requirements, adequate prehospital service, etc (nodes 1 and 4). Proper supply chain management system is also a reflection of effective hospital management, resulting in an arc between node 5 and 1. Treatment process quality along with the information technology implementation, fall within the ambit of hospital management, which leads to formation of edges from node 1 to node 6 and node 7 respectively.

In the case of Pre-hospital and Hospital Ambience (HA), which is represented by node 2, there is direct influence on Treatment process quality as pre-hospital notification affects the incoming treatment process preparedness (Cohen et al., 2008). However, the Hospital ambience gets influenced by Management (Node 1), Human resource (Node 2) and Support Facilities (Node 3) for obvious reasons.

Similar interrelationships among other nodes in the emergency service quality digraph are developed in the same way and are illustrated in Figure 3.1 and summarized in Table 3.1. While the digraph provides a visual depiction of the interconnections, further analysis requires the development of an equivalent matrix, a topic to be explored in the subsequent section.

**Table 3.1**: Inter-Relationships among the factors.

| Factor | Influences | Influenced by | Reasons for Influence |
|---|---|---|---|
| **Hospital Management and Administration (HM)** | HPC, SF, HA, SCM, TPQ, ITI | HPC, ITI, SCM | Effective administration and management shape training, resource allocation, ambience, supply chain, treatment processes, and IT integration. |
| **Healthcare Personnel Competencies (HPC)** | SF, HA, TPQ, ITI, HM | HM, HA | Management influences ongoing training and deployment, impacting personnel competencies. Pre-hospital notification also affect Competency. Competent personnel ensure Effective management. |
| **Support Facilities (SF)** | HA, HPC, TPQ | HM, HPC | Competent personnel contribute to the effective utilization and maintenance of support facilities. Management decisions influence resource allocation to SF. |
| **Pre-Hospital and Hospital Ambience (HA)** | TPQ | HM, HPC, SF | Support facilities maintenance and efficient supply chain contribute to a positive ambience. - Management decisions shape overall hospital ambience. |

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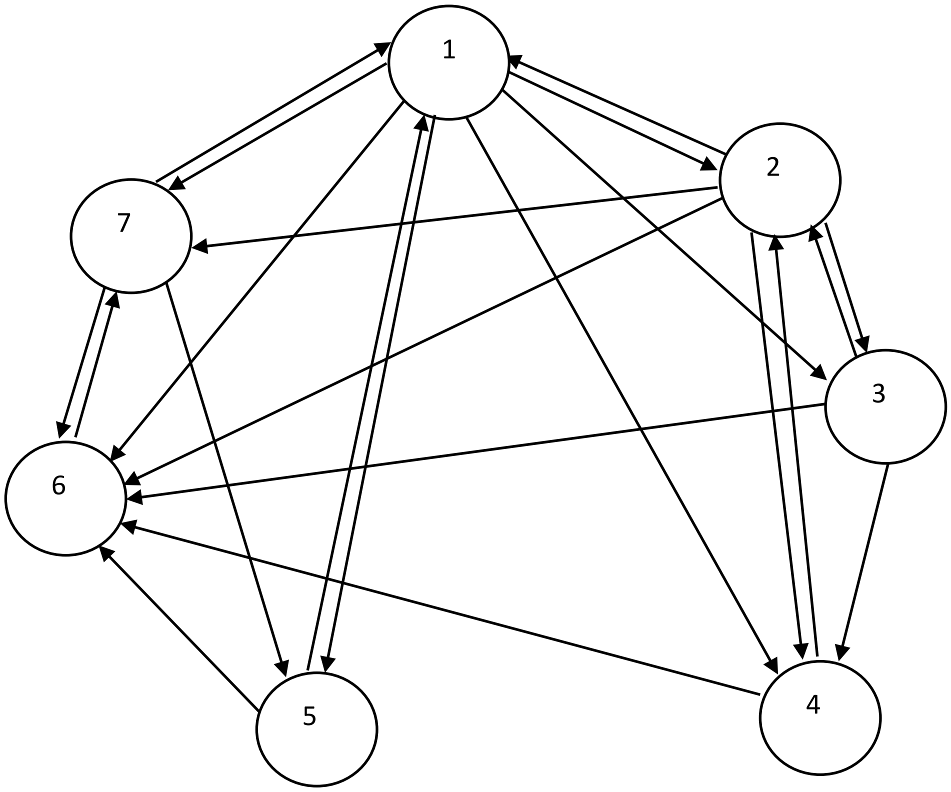
Table 3.1 (continued)

| Factor | Influences | Influenced by | Reasons for Influence |
|---|---|---|---|
| **Supply Chain Management (SCM)** | TPQ, HA | HM, ITI | Efficient SCM ensures timely availability of resources, positively impacting treatment quality. Management decisions influence SCM protocols and resource allocation. |
| **Treatment Process Quality (TPQ)** | ITI | HM, HPC, SF, HA, SCM | Effective administration contributes to streamlined processes, reducing errors and improving treatment quality. Competent personnel enhance accuracy and effectiveness. |
| **Information Technology Integration (ITI)** | SCM, HM, TPQ | HM, HPC, TPQ | Management decisions drive IT integration for enhanced hospital operations. Competent staff ensures effective use of IT systems. Quality treatment processes necessitate effective IT integration. Efficient supply chain management (SCM) can benefit from information technology integration (ITI) in terms of inventory management systems, efficient communication with suppliers, and streamlined processes. |




1. Hospital Management and Administration (HM),
2. Healthcare Personnel Competencies (HPC),
3. Support facilities (SF),
4. Pre-Hospital and Hospital ambience (HA),
5. Supply chain management (SCM),
6. Treatment process quality (TPQ),
7. Information Technology Integration (ITI)

**Fig. 3.1** Emergency department service quality digraph

**3.1 Matrix representation of the digraph:**

This section focuses on the development of a representative matrix for the service quality directed graph to ensure a comprehensive understanding of the mutual interrelationships among the seven identified factors which influence quality of service in a Hospital ED. The initial digraph model (Figure 3.1) may lack certain edges, leading to potential omissions in its matrix expression. To address this, a new digraph model (Figure 3.2) is introduced, incorporating all conceivable mutual interrelationships among identified factors.

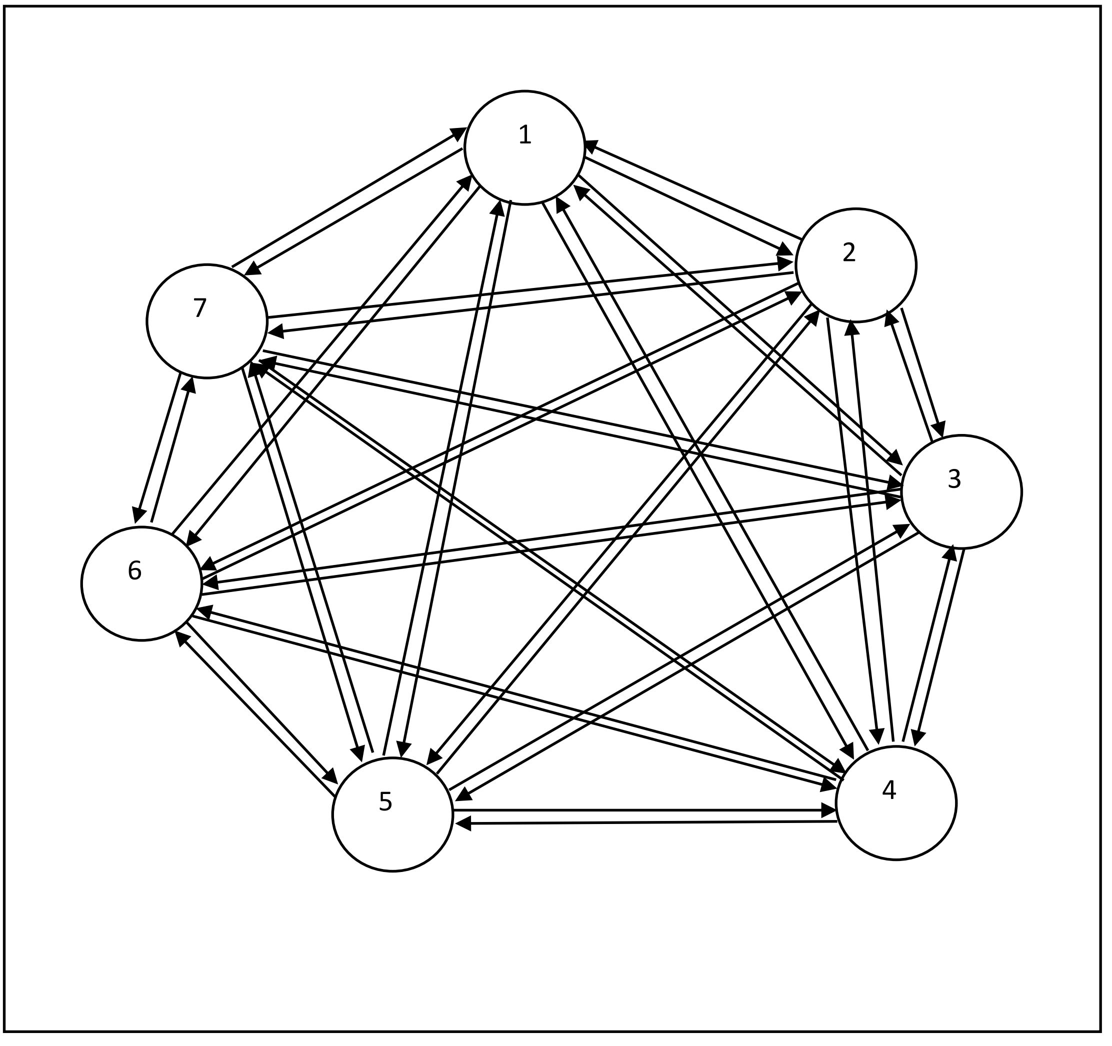



**Fig. 3.2** Digraph showing all possible edges

Figure 3.2 represents a directed graph that fulfills the conditions for including all possible influences among the identified factors. A one-to-one matrix derived from this digraph, termed the Service Quality Matrix ($Q_F$) as per James and James (2020), is shown as expression (3.1), offering insights into the characteristics of service quality in emergency healthcare systems.

$$Q_F = \begin{bmatrix} F_1 & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} & r_{17} \\ r_{21} & F_2 & r_{23} & r_{24} & r_{25} & r_{26} & r_{27} \\ r_{31} & r_{32} & F_3 & r_{34} & r_{35} & r_{36} & r_{37} \\ r_{41} & r_{42} & r_{43} & F_4 & r_{45} & r_{46} & r_{47} \\ r_{51} & r_{52} & r_{53} & r_{54} & F_5 & r_{56} & r_{57} \\ r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & F_6 & r_{67} \\ r_{71} & r_{72} & r_{73} & r_{74} & r_{75} & r_{76} & F_7 \end{bmatrix} \quad (3.1)$$

The permanent of this matrix, denoted as Per($Q_F$), is referred to as the Service Quality Function (SQF) as per James and James (2020). The SQF contains many invariant terms which represent the service quality factors and their influences among each other. The permanent function being standard matrix operation in combinatorial mathematics (Jurkat & Reyser, 1966), is recognized for its positive nullity (all terms being positive) and is considered a perfect interpretation of the graph theory approach as per Singh and Bapat (2017). Researchers have extensively applied the concept of developing directed graphs (digraphs) and their equivalent matrices for decision making, along with the evaluation of the permanent of matrices, across various domains. Noteworthy examples include its utilization in service quality evaluation of automobile garages (James & James, 2020), assessment of sustainability risk for mechanical systems (Anand et al., 2016).

The general expression for calculating SQF, the permanent of the quality matrix $Q_F$, i.e. Per($Q_F$), is given in expression 3.2. The permanent of a matrix is a concept similar to the determinant but without the alternating signs.

For a n x n matrix, $Q_F$ , the permanent, denoted as Per($Q_F$), is defined as:

$$
\begin{aligned}
Per(Q_F) = {} & \prod_{i=1}^{N} F_i + \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{ji})F_kF_lF_m \dots\dots F_N \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{jk}r_{ki} + r_{ik}r_{kj}r_{ji})F_lF_m \dots\dots F_N \\
& + \Bigg\{ \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{ji})(r_{kl}r_{lk})F_m \dots\dots F_N \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{jk}r_{ll}r_{li} + r_{il}r_{lk}r_{kj}r_{ji})F_m \dots\dots F_N \Bigg\} \\
& + \Bigg[ \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{ji})(r_{kl}r_{lm}r_{mk} + r_{km}r_{ml}r_{lk})F_n \dots\dots F_N \\
& + \sum_i \sum_j \sum_k \sum_l \sum_m \dots\dots \sum_N (r_{ij}r_{jk}r_{lk}r_{lm}r_{mi} + r_{im}r_{ml}r_{lk}r_{kj}r_{ji})F_n \dots\dots F_N \Bigg] \\
& + \dots
\end{aligned}
\tag{3.2}
$$

Unlike the determinant, the permanent does not involve alternating signs.

Let's consider a 2x2 matrix A as an example:

$$
A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}
$$

The permanent of A is calculated as:

$$
Per(A) = a_{11}a_{22} + a_{12}a_{21} \tag{3.3}
$$

For a 3x3 matrix B:

$$B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}$$

The permanent of B is calculated as:

$$Per(B) = b_{11}b_{22}b_{33} + b_{11}b_{23}b_{32} + b_{12}b_{21}b_{33} + b_{12}b_{31}b_{23} + b_{13}b_{21}b_{32} + b_{13}b_{31}b_{22} \quad (3.4)$$

The idea is the same for higher order matrices.

The diagonal element $F_i$ in equation (3.1) represents the i^th factor, and the non-diagonal member $r_{ij}$ represents the degree of influence of the i^th factor on the j^th factor and vice-versa. The SQF accommodates all possible terms of the matrix, including service quality factors, degrees of influence, and their combinations.

The equivalent matrix $QF_1$, developed from the directed graph shown in Figure 3.1, is represented as equation (3.5):

$$QF_1 = \begin{bmatrix} F_1 & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} & r_{17} \\ r_{21} & F_2 & r_{23} & r_{24} & 0 & r_{26} & r_{27} \\ 0 & r_{32} & F_3 & r_{34} & 0 & r_{36} & 0 \\ 0 & r_{42} & 0 & F_4 & 0 & r_{46} & 0 \\ r_{51} & 0 & 0 & 0 & F_5 & r_{56} & 0 \\ 0 & 0 & 0 & 0 & 0 & F_6 & r_{67} \\ r_{71} & 0 & 0 & 0 & r_{75} & r_{76} & F_7 \end{bmatrix} \quad (3.5)$$

It is observed that some non-diagonal terms in matrix $QF_1$ are zero, resulting in the absence of certain terms in the expression (3.2). The following section deals with the evaluation of the service quality index (SQI).

## 3.2 Evaluation of Service Quality

In the preceding section, we have studied that the SQF represents the service quality of any service-based organization. Building on this perspective, the concept of service quality is derived from the Service Quality Function, encompassing terms that involve both individual factors ($F_i$) and their mutual influences over each other ($r_{ij}$). The calculation of service quality expression involves obtaining numerical values for both the diagonal members, denoted as ($F_i$), and the non-diagonal members, indicated as ($r_{ij}$), within the service quality matrix.

### 3.2.1 Evaluation of Diagonal Elements

The initial step in the quantification process involves assessing the diagonal elements of the matrix $QF_1$, denoted as ($F_i$). Each service quality factor ($F_i$) encompasses various sub-factors ($F_{ij}$) as discussed in Chapter 2, where i ranges from 1 to 7, and j ranges from 1 to m. Table 2.2 provides a comprehensive list of these factors and their respective sub-factors.

The assigned score, represented as $S_{ij}$ pertains to the $j^{th}$ sub-factor which is a subset of $i^{th}$ major factor. For example, the pre-hospital notification sub-factor $HA_4$ will have score term of $S_{14}$ over the major factor HA. In line with existing literature James and James (2020), a scale of 0-1-2 is adopted for assigning values to $S_{ij}$. This scale involves discrete values corresponding to different levels, such as none (0), average (1), and high (2) for sub-factors. Recognizing the potential subjectivity in this assignment, a team-based approach is employed to mitigate biases. The team, comprised of professionals associated with healthcare, collectively performs this task.

As an illustrative example, the service quality factor "Hospital Management (HM)" is chosen, and Table 3.2 is devised to guide the assignment of levels to its seven sub-factors. The assigned values ($S_{ij}$) on a scale of 0 to 2 are detailed in Table 3.2, with clear descriptions provided for each sub-factor. Following a similar methodology, Tables 3.3–3.8 are created for the remaining six major factors: HPC, SF, HA, SCM, TPQ, ITI. These tables collectively serve as a reference for the quantitative assessment of sub-factors associated with each service quality factor.

In the process of quantifying $F_i$ in the evaluation of service quality, an essential consideration is assigning weights (Wi) to each major factor. Equal contributions from each major factor are not assumed, acknowledging that factors may have varying degrees of importance in ensuring overall service quality. The evaluation of "$F_i$" is expressed as follows:

$$F_i = W_i\left(\sum_{j=1}^{m} S_{ij}\right) \quad (3.6)$$

where (i = 1, 2, ..., 7) represents the service quality factors, and (j = 1, 2, ..., m) signifies the subfactors.

To determine the weights (Wi), the Analytic Hierarchy Process (AHP) procedure, as introduced by Saaty (1990), is incorporated. AHP is a method designed for multi criteria decision-making within a hierarchical system, proving valuable during subjectivity issues that involve human perceptions and decisions (James & James, 2020). Thus, the AHP methodology is employed in assigning weights to the service quality factors for Hospital Emergency Department.

The AHP algorithm includes the following steps:

1. Constructing pairwise comparison matrices: Creation of a (n x n) square matrix where each element ($a_{ij}$) represents the relative importance of criterion i compared to criterion j. The data for the matrix is obtained by survey of experts. The matrix is reciprocal in nature i.e.

$$(a_{ij} = 1/a_{ji} \; for \; all \; i \neq j). \tag{7}$$

   In this research, the nine-point Saaty scale is used to convert a single opinion sentence into a numerical measure for comparison (1/9: "extremely less important over another", 1/7: "very strongly less important", and so on) where 1 indicates equal importance and higher values indicate stronger preference for the row criterion over the column criterion. Expert opinion was taken by the means of subjective questionnaire with the above given options and hence, further calculations were made after taking primary data.

2. Calculation of weights: For the comparison matrix, the Steps for calculation of weights are given in Appendix-I.

3. Consistency checking: These comparison matrices were solved using AHP approach. In this method, the consistency ratio (CR) value should be less than or equal to 0.1 to ensure the reliability of data collected. It measures the consistency of the expert's judgement. If CR value is more than 0.1 or 10 percent, the responses are removed.

**Table 3.2:** Assigning Values for HM

| **Sub-factors $F_{ij}$** | **None (0)** | **Average (1)** | **High (2)** |
|---|---|---|---|
| ($F_{11}$): Recruitment, and training of healthcare professionals (doctors and paramedics, staff, etc.) | Poor recruitment policy. Inexperienced Doctors and staff for emergency department. | Interns and PG students are mostly deployed and trained during the job. | Highly experienced professionals of Emergency care are deployed and recruited. |
| ($F_{12}$): Efficient Scheduling of Consultants/Faculty posting in the emergency department. | None Present | There is little bit of scheduling but the number of Consultants/Faculty visiting is less | Proper Scheduling so that an Experienced senior Consultant/faculty doctor is always present. |
| ($F_{13}$): Rotation of medical personnel and nursing students from different disciplines in ED. | No policy in place | Policy is present but not in use | Policy in use |
| ($F_{14}$): Dedicated post of doctors, nurses, and paramedics for the emergency department | No dedicated personnel | Dedicated personnel are very few in number and that too staff and paramedics. | Dedicated personnel present. |

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Table 3.2 (continued)

| **Sub-factors $F_{ij}$** | **None (0)** | **Average (1)** | **High (2)** |
|---|---|---|---|
| ($F_{15}$): Feedback collection from patients, surveys, and continuous improvement | No feedback collection mechanism present | Present but not effectively used | Effective usage and analysis done |
| ($F_{16}$): Implementation of TRIAGE system for effective patient prioritization. | TRIAGE system absent. | Triage system is present but not followed. | Efficient triage system present and functioning. |
| ($F_{17}$): Strategic Financial Management | No utilization of funds for ED. | Partial utilization and that too not for ED. | Full effective utilization and that too on ED. |

**Table 3.3:** Assigning Values for HPC

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| ($F_{21}$): Communication Skills of Staff: Patient Engagement, Grief Counselling, Empathy, Shared Decision making | Minimal communication with no empathy or inappropriate behaviour | Full content sharing with empathy but no shared decision making | Full content sharing with empathy and shared decision making. |
| ($F_{22}$): Cognitive Skills | Less agility in personnel to handle surge situation. | Able to handle surge situation for a relatively short duration. | Able to handle Surge situation for long time. |
| ($F_{23}$): Multitasking Capacity | Personnel are trained to work in only one domain | In two domains. | More than two domains. |
| ($F_{24}$): Continuous Education and training | No training in Emergency medicine and scenario. | Very few are trained. | All members are trained and educated yearly. |

**Table 3.4:** Assigning Values for SF

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| ($F_{31}$): Availability of ED protocols, manuals, etc | No documented protocols and manuals | Documented but not implemented. | Documented and implemented. |
| ($F_{32}$): Routine Inspection of ED equipment | No routine inspection | Inspection done but no manual. | Inspection done and manual present. |
| ($F_{33}$): Availability of Essential Medicines | Essential medicines absent. | Essential medicine quantity inadequate. | Adequate essential medicine present. |
| ($F_{34}$): Safety Plans in Hospital | No plans or policy in place. | Policy is present but no mock drills. | Effective implementation of plans and staff training. |
| ($F_{35}$): Point of Care Labs | Essential labs not present. | Labs are present but no prioritization for emergency department. | Prioritization given for emergency cases. |
| ($F_{36}$): Blood bank services 24x7 in-house | Not present. | Present but not 24x7 | 24x7 state- of-the art Services. |

**Table 3.5:** Assigning Values for HA

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| $(F_{41})$: Access to simple, integrated and free phone numbers for Ambulance | No integration with emergency numbers (ex. 108) | Integrated but inadequate response. | Adequate response and integration. |
| $(F_{42})$:24x7 in-house ambulance with ALS and BLS | None | Inadequate with no ALS ambulance or dedicated staff. | Adequate with all the services and dedicated staff. |
| $(F_{43})$: Tie-up with third party ambulance | None present. | Tie up is there but poor communication with service provider | Proper communication in place. |
| $(F_{44})$: Pre-Hospital Notification | Does not get Notification. | Gets notification but coordination with ED lacking. | Properly coordinated. |
| $(F_{45})$: Easy and direct access to ED | Access not direct. | Inside Emergency with easy access. | Outside emergency with easy access. |
| $(F_{46})$: Provision of PPE and safety equipment | None present | Inadequate | PPE and safety equipment is present in optimum quantity. |
| $(F_{47})$: Availability of beds, buffer beds planning, emergency operative surgeries | Beds are inadequate. | Buffer beds absent. | Optimum number of beds available. |
| $(F_{48})$: Cleanliness | Poor cleanliness of emergency room, toilets etc | Average Cleanliness | Neat and clean environment. |
| $(F_{49})$: Lighting | Poor lighting | Ordinary lighting not suitable for ED. | Proper Lighting as per ED requirements. |

**Table 3.6:** Assigning Values for SCM

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| ($F_{51}$): Inventory Management Systems availability | Absent | System present but poor implementation | Complete usage. |
| ($F_{52}$): Equipment supplier selection availability | Absent | System present but poor implementation | Complete usage. |
| ($F_{53}$): Medicine Supplier Selection availability | No system available | System present but poor implementation | Complete usage. |
| ($F_{54}$): Waste Management availability | No system available | System present but poor implementation | Complete usage. |

**Table 3.7:** Assigning Values for TPQ

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| ($F_{61}$): Dedicated Staff for gap identification | Not Present | Staff available but irregular audits. | Regular Audits. |
| ($F_{62}$): Diagnostic Accuracy | No monitoring system present | System available but poor implementation | Complete utilization. |
| ($F_{63}$): Occurrence of Treatment/medication errors | No monitoring system present | System available but poor implementation | Complete utilization. |
| ($F_{64}$): Death Review Committee | Not present | Present but rare meetings. | Regular Meeting and implementation of recommendations. |
| ($F_{65}$): Standardized Treatment Process | SOPs not present | SOPs present but not followed. | SOPs present and followed. |

**Table 3.8:** Assigning Values for ITI

| **Sub-factors $F_{ij}$** | **None** | **Average** | **High** |
|---|---|---|---|
| $(F_{71})$: ERP system availability | Absent | Present but not fully implemented. | Full implementation and utilization, |
| $(F_{72})$: Electronic Health Record | Absent | Present but not fully implemented. | Complete usage. |
| $(F_{73})$: Patient Registration System | Absent | Present but not fully implemented. | Complete usage. |
| $(F_{74})$: ED Surveillance System | Absent | Present but not fully implemented. | Complete usage. |
| $(F_{75})$: Data Retrieval System | Absent | Present but not fully implemented. | Fast and efficient system present. |

### 3.2.2 Evaluation of non-Diagonal Elements

In the context of quantifying the non-diagonal elements " $r_{ij}$", these elements represent the degree of relationship among the identified factors. A scale of 0-4 is used for assigning values, where "0" signifies no influence, "4" indicates high influence, and the intermediary levels include "above average (3)," "average (2)," and "minor (1)" as per James and James (2020).

For example, the influence of Hospital Management and Administration (HM) on different factors within the ED might exhibit high influence on Healthcare Personnel Competencies (HPC) such as recruitment and training, above-average influence on Information Technology Integration (ITI) for efficient hospital operations, and average influence on Supply Chain Management (SCM) to ensure timely availability of resources. Meanwhile, the influence of HPC on other factors could be categorized based on the observed impact, using the same scale. Table 3.9 encapsulates the above values of " $r_{ij}$".

**Table 3.9:** Degree of influence among the quality factors

| S. No. | Major Factor | High | Above Average | Average | Minor | None |
|---|---|---|---|---|---|---|
| | | $r_{ij} = 4$ | $r_{ij} = 3$ | $r_{ij} = 2$ | $r_{ij} = 1$ | $r_{ij} = 0$ |
| 1 | Hospital Management and Administration (HM) | 2 | 4,5,6 | 3 | 7 | |
| 2 | Healthcare Personnel Competencies (HPC) | 6 | 1 | 4 | 3,7 | 5 |
| 3 | Support Facilities (SF) | 2 | 6 | | 4 | 1,7,5 |
| 4 | Pre-Hospital and Hospital Ambience (HA) | | 2 | 6 | | 1,3,5,7 |
| 5 | Supply Chain Management (SCM) | 6 | | 1 | | 2,3,4,7 |
| 6 | Treatment Process Quality (TPQ) | | | | 7 | 1,2,3,4,5 |
| 7 | Information Technology Integration (ITI) | 5 | 1 | | 6 | 2,3,4 |

### 3.3 Evaluation of Service Quality Index

The SQI rating serves as a quantifiable indicator reflecting the quality of services provided by the ED. It is derived from the Service Quality Function (SQF), as established in the earlier section, incorporating values for $F_i$ and $r_{ij}$. Greater absolute value of SQF signifies a greater quality of service offered by the organisation. However, the absolute numerical value of the SQI may become unwieldy if excessively high scale values for "$F_i$" and "$r_{ij}$" are used. To address this, two additional metrics are introduced: Ideal Service Quality Index (ISQI) and Service Quality Index Ratio (SQIR) (James & James, 2020).

ISQI represents the highest service quality rating achievable by an ED.

SQIR is computed as follows

$$SQIR = \frac{SQI\ of\ an\ ED}{ISQI\ of\ an\ ideal\ ED} \tag{3.7}$$

An ideal scenario is denoted by SQIR equalling 1. The SQIR value ranges from 0 to 1. Ideally, it should approach 1. A lower SQIR ratio indicates areas for improvement in rendering quality service for the ED.

### 3.4 Sensitivity Analysis of the SQI Model

The use of sensitivity analysis is needed to be able to examine the impact of a variation within one or more variables of a mathematical model with reference to the output. This change of variable could either be positive or negative. It is commonly used in models which are used for taking decisions, where according to the sensitivity analysis one can determine the variables that influence the decisions. To analyse the sensitivity of this model, SQI value changes is observed by varying the value of each service quality factor which is located at the diagonal entry in the service quality matrix, one at a time. We are not going to change the value of non-diagonal entries which show the degree of influence of each factor over one-another. In turn, sensitivity analysis will prove to be useful for the management of the Hospital ED. The sensitivity analysis will enable us to pin-point the quality factors that, if enhanced, will significantly increase the value of the SQI. This will allow the hospital administrators to concentrate more on those factors especially in order to attain better service quality.

### 3.5 SQI evaluation steps

Based on the methodology given in previous sub-sections 3.1-3.4, for service quality index calculation for the Hospital ED, steps for evaluation are enumerated below:

(1) Hospital selection and identification of its service quality factors and associated sub-factors.

(2) Giving the values to non-diagonal elements which show the degree of influence of the one factor over the other by taking expert opinion, i.e. $r_{ij}$ as discussed in Section 3.2.2.

(3) Evaluation of the diagonal elements i.e. the identified factors $F_i$ for the selected hospital in step 1, using equation (6) and Tables (4 to 10). Refer section 3.2.1.

(4) Development of the directed graph and equivalent matrix with $F_i$ and $r_{ij}$ as diagonal and non-diagonal elements using steps 1 to 3 and section 3.1.

(5) Evaluate the SQI which is the permanent of the matrix developed in step 4 using on equation (2). Additionally, calculate the service quality index ratio (SQIR) using equation (7)

(7) At last, the sensitivity analysis is done to test the model's robustness.

# CHAPTER 4

## RESULTS AND DISCUSSION

### 4.1 CASE STUDY FOR ILLUSTRATION OF THE PROPOSED MODEL:

To illustrate the above model in chapter 3 for the SQI evaluation, a case study of two Hospitals of Delhi was undertaken. Both had a working Emergency department which catered to large population of Delhi. Let us denote them by Hospital A and Hospital B respectively. The primary data was collected by interview of senior doctors and administrators of their respective Emergency Department. Firstly, the weightage ($W_i$) for each major factor is calculated using the AHP procedure as discussed in Section 3.2.1. For this, a pairwise comparative matrix of seven identified factors is created using Saaty's 1–9 scale by taking feedback from experts as well as taking help from Table 3.9. It is shown as matrix "C".

$$\begin{array}{cc} & \begin{array}{ccccccc} HM & HPC & SF & HA & SCM & TPQ & ITI \end{array} \\ C = & \begin{bmatrix} 1 & 1 & 1 & 1 & 2 & 1 & 5 \\ 1 & 1 & 1 & 1 & 2 & 1 & 2 \\ 1 & 1 & 1 & 2 & 2 & 0.5 & 2 \\ 1 & 1 & 0.5 & 1 & 1 & 0.2 & 1 \\ 0.5 & 0.5 & 0.5 & 1 & 1 & 0.2 & 1 \\ 1 & 1 & 2 & 5 & 5 & 1 & 5 \\ 0.2 & 0.5 & 0.5 & 1 & 1 & 0.2 & 1 \end{bmatrix} \begin{array}{c} HM \\ HPC \\ SF \\ HA \\ SCM \\ TPQ \\ ITI \end{array} \end{array}$$

The CR value came out to be 0.042 which indicated the consistency of the data. Weight $W_i$ for each factor calculated using AHP is tabulated in Table 4.1.

**Table 4.1:** Relative weights of the major factors.

| S. No. | Service Quality Factor | Normalized relative weight $W_i$ |
|---|---|---|
| 1 | HM | 0.18 |
| 2 | HPC | 0.15 |
| 3 | SF | 0.15 |
| 4 | HA | 0.10 |
| 5 | SCM | 0.07 |
| 6 | TPQ | 0.28 |
| 7 | ITI | 0.07 |

From Table 4.1, we can clearly deduce that the Treatment Process Quality (TPQ) factor carries the highest weight (28%) when compared with other 6 factors. This implies that the main focus of a hospital should be to enhance the medical interventions by using state of the art technology so as to reduce the errors in diagnosis. This is followed by the Hospital Management factor (18%) which entails the processes such as financial management, Human resource management, etc. Healthcare personnel competency and support facilities carry equal weight of 15% followed by Pre-hospital and hospital ambience at 10%. The last priority is given to SCM and ITI, both tied at seven percent. This AHP solution is used to calculate the matrix diagonal element value by using equation 3.6. The AHP methodology played a crucial role in assigning weightages to the barriers and sub-barriers, contributing to a more robust evaluation process by finding out local as well as global ranking and weights. Each major factor has been evaluated on the scale 0-2 for $S_{ij}$. Based on this, Table 4.2 is developed.

**Table 4.2**: Evaluation of Sub-factors

| Factor $F_i$ | Sub-factor | Hospital A | | Hospital B | |
|---|---|---|---|---|---|
| | | Evaluation | Sub-factor Score $S_{ij}$ | Evaluation | Sub-factor Score $S_{ij}$ |
| HM ($F_1$) | $F_{11}$ | High | 2 | Average | 1 |
| | $F_{12}$ | Average | 1 | High | 2 |
| | $F_{13}$ | Average | 1 | High | 2 |
| | $F_{14}$ | None | 0 | None | 0 |
| | $F_{15}$ | Average | 1 | None | 0 |
| | $F_{16}$ | Average | 1 | High | 2 |
| | $F_{17}$ | High | 2 | Average | 1 |
| HPC ($F_2$) | $F_{21}$ | High | 2 | Average | 1 |
| | $F_{22}$ | Average | 1 | High | 2 |
| | $F_{23}$ | Average | 1 | Average | 1 |
| | $F_{24}$ | None | 0 | Average | 1 |
| SF ($F_3$) | $F_{31}$ | High | 2 | High | 2 |
| | $F_{32}$ | Average | 1 | High | 2 |
| | $F_{33}$ | Average | 1 | High | 2 |
| | $F_{34}$ | High | 2 | Average | 1 |
| | $F_{35}$ | High | 2 | Average | 1 |
| | $F_{36}$ | Average | 1 | None | 0 |
| HA ($F_4$) | $F_{41}$ | High | 2 | High | 2 |
| | $F_{42}$ | Average | 1 | High | 2 |
| | $F_{43}$ | High | 2 | None | 0 |
| | $F_{44}$ | None | 0 | Average | 1 |

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Table 4.2 (continued)

| Factor $F_i$ | Sub-factor | Hospital A Evaluation | Hospital A Sub-factor Score $S_{ij}$ | Hospital B Evaluation | Hospital B Sub-factor Score $S_{ij}$ |
|---|---|---|---|---|---|
| | $F_{45}$ | Average | 1 | High | 2 |
| | $F_{46}$ | High | 2 | Average | 1 |
| | $F_{47}$ | Average | 1 | High | 2 |
| | $F_{48}$ | Average | 1 | High | 2 |
| | $F_{49}$ | Average | 1 | Average | 1 |
| SCM ($F_5$) | $F_{51}$ | High | 2 | None | 0 |
| | $F_{52}$ | Average | 1 | High | 2 |
| | $F_{53}$ | High | 2 | Average | 1 |
| | $F_{54}$ | Average | 1 | High | 2 |
| TPQ ($F_6$) | $F_{61}$ | None | 0 | Average | 1 |
| | $F_{62}$ | Average | 1 | None | 0 |
| | $F_{63}$ | Average | 1 | Average | 1 |
| | $F_{64}$ | None | 0 | High | 2 |
| | $F_{65}$ | Average | 1 | High | 2 |
| ITI ($F_7$) | $F_{71}$ | Average | 1 | High | 2 |
| | $F_{72}$ | High | 2 | High | 2 |
| | $F_{73}$ | High | 2 | High | 2 |
| | $F_{74}$ | Average | 1 | None | 0 |
| | $F_{75}$ | Average | 1 | High | 2 |

The process of evaluation for the Hospital is illustrated with the first factor "Hospital management and administration (HM)". For Hospital A, the sub-factor scores $S_{ij}$ of the hospital management are given in Table 4.2. Using equation (6), the HM($F_{1A}$) factor value of Hospital= $0.18 \times (2 + 1 + 1 + 0 + 1 + 1 + 2) =$

1.44, with $W_i = 0.18$ (Table 4.1) and $\sum S_{ij} = 8$ (Table 4.2). For Hospital B, this value comes out to be $0.18 \times 8 = 1.44$ also. Notice the differences in scores for both the hospitals, but the summation comes out to be same for HM factor and hence $F_{1B}$ value comes out to be same.

For the second factor i.e. Healthcare personnel competencies, the value of $F_{2A} = 0.15 \times 4 = 0.60$ for Hospital A. the value comes out to be 0.75 for Hospital B which shows a slight upper hand of Hospital B when the Human resource potential is compared with that of Hospital A.

For the third factor i.e. Support Facilities (SF), the value of summation of Sub factor scores is 9 which bring out the value of $F_{3A} = 0.15 \times 9 = 1.35$. For Hospital B, this value comes out to be $F_{3B} = 0.15 \times 8 = 1.20$. This illustrates an upper hand of Hospital A due to its robust Support Infrastructure. The value of $4^{th}$ factor $S_{ij}$ for Hospital A and B is 11 and 13 respectively. Thus, the value of $F_{4A} = 0.10 \times 11 = 1.1$ and $F_{4B} = 0.10 \times 13 = 1.3$. The value of $5^{th}$ factor i.e. Supply Chain management $S_{ij}$ for Hospital A and B is 6 and 5 respectively. Thus, the value of $F_{5A} = 0.07 \times 6 = 0.42$ and $F_{5B} = 0.07 \times 5 = 0.35$ indicating slight better SCM capabilities for Hospital A. For the sixth factor i.e. Treatment process quality (TPQ), which has the highest relative weight as shown in Table 4.1, the value of $S_{ij}$ for Hospital A is 3 and that of B is 6. Thus, the value of $F_{6A} = 0.28 \times 3 = 0.84$ and $F_{6B} = 0.28 \times 6 = 1.68$. ITI's $S_{ij}$ for Hospital A and B is 7 and 8 respectively. Thus, the value of $F_{7A} = 0.07 \times 7 = 0.49$ and $F_{7B} = 0.07 \times 8 = 0.56$ indicating better IT implementation capabilities for Hospital B.

The service quality matrix representation for the Hospital A, i.e. $QF_{1A}$ is developed from Figure 3.1 is illustrated below. The values are calculated using Table 4.1 and 4.2 along with equation 3.6 as shown in the preceding paragraph. The directed graph for service quality of both the hospitals is shown in Figure 4.1.

$$QF_{1A} = \begin{bmatrix} 1.44 & 4 & 2 & 3 & 3 & 3 & 1 \\ 3 & 0.60 & 1 & 2 & 0 & 4 & 1 \\ 0 & 4 & 1.35 & 1 & 0 & 3 & 0 \\ 0 & 3 & 0 & 1.1 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 0.42 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.84 & 1 \\ 3 & 0 & 0 & 0 & 4 & 1 & 0.49 \end{bmatrix}$$

The SQF value is obtained from evaluating permanent function of this matrix $QF_{1A}$ on the lines of equation (3.2).

Per $(QF_{1A}) = 6416.84$ is calculated using online software tool (dCode, 2023) whose sample screenshot is provided in Appendix-II. Thus, the service quality index (SQI) for the hospital A is 6417.

Similarly, for Hospital B, i.e. $QF_{1B}$ is illustrated below.

$$QF_{1B} = \begin{bmatrix} 1.44 & 4 & 2 & 3 & 3 & 3 & 1 \\ 3 & 0.75 & 1 & 2 & 0 & 4 & 1 \\ 0 & 4 & 1.20 & 1 & 0 & 3 & 0 \\ 0 & 3 & 0 & 1.3 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 0.35 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.68 & 1 \\ 3 & 0 & 0 & 0 & 4 & 1 & 0.56 \end{bmatrix}$$

The SQF value is obtained from evaluating permanent function of this matrix $QF_{1B}$ i.e. Per $(QF_{1B}) = 6874.74$.

Thus, the service quality index (SQI) for the hospital B is 6875.

Determining the Ideal Service Quality Index (ISQI) for service quality evaluation requires imagining a perfect hospital scenario. Let's take Hospital Management (HM) as an example. This factor consists of 7 sub-factors, each with a maximum score of 2 according to the established scoring criteria.

When all sub-factors of hospital management perform optimally, they achieve a maximum score of 14. This is then multiplied by the relative weight of Hospital management, which is 0.18 according to Table 4.1. This calculation yields the ideal factor value for Hospital management ($F_1$), essentially representing the maximum contribution it can make to overall hospital management success under perfect conditions.

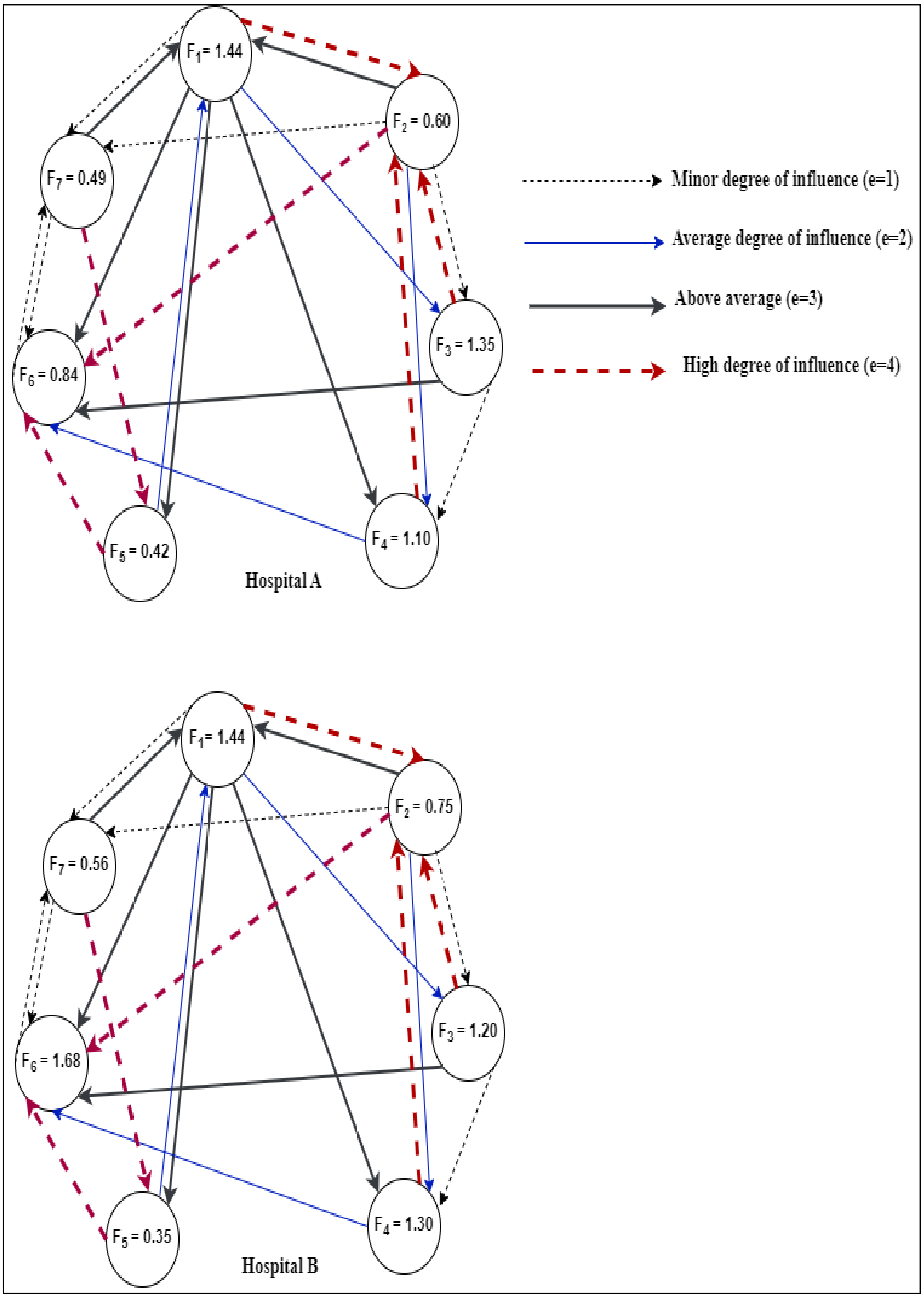


**Fig. 4.1** Service Quality Directed Graph for Hospitals A and B

So,

$$F_1 = W_1 \times \sum_{1}^{7} S_{1j} = 0.18 \times 14 = 2.52$$

Similarly,

$$F_2 = W_2 \times \sum_{1}^{4} S_{2j} = 0.15 \times 8 = 1.20$$

$$F_3 = W_3 \times \sum_{1}^{6} S_{3j} = 0.15 \times 12 = 1.80$$

$$F_4 = W_4 \times \sum_{1}^{9} S_{4j} = 0.10 \times 18 = 1.80$$

$$F_5 = W_5 \times \sum_{1}^{4} S_{5j} = 0.07 \times 8 = 0.56$$

$$F_6 = W_6 \times \sum_{1}^{5} S_{6j} = 0.28 \times 10 = 2.80$$

$$F_7 = W_7 \times \sum_{1}^{5} S_{7j} = 0.07 \times 10 = 0.70$$

Then, with all $F_i$ values set to maximum, the equivalent matrix corresponding to an ideal hospital is developed. This ideal matrix is represented as $QF_{1(ideal)}$

$$QF_{1(ideal)} = \begin{bmatrix} 2.52 & 4 & 2 & 3 & 3 & 3 & 1 \\ 3 & 1.2 & 1 & 2 & 0 & 4 & 1 \\ 0 & 4 & 1.8 & 1 & 0 & 3 & 0 \\ 0 & 3 & 0 & 1.8 & 0 & 2 & 0 \\ 2 & 0 & 0 & 0 & 0.56 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.8 & 1 \\ 3 & 0 & 0 & 0 & 4 & 1 & 0.7 \end{bmatrix}$$

Per $(QF_{1(ideal)}) = 11744.9$

Thus, the service quality index (SQI) for the ideal hospital ED is 11745 which is denoted as Ideal SQI i.e. ISQI.

For Hospital A, the ratio of its service quality to that of the ideal ED is calculated below

$$SQIR_A = \frac{SQI\ of\ Hospital\ A}{ISQI\ of\ an\ ideal\ Hospital} = \frac{6417}{11745} = 0.54$$

Hence, the hospital A's ED is around 50% less efficient than the Ideal ED.

For Hospital B,

$$SQIR_B = \frac{SQI\ of\ Hospital\ B}{ISQI\ of\ an\ ideal\ Hospital} = \frac{6875}{11745} = 0.58$$

It is to be noted that Hospital B has a higher SQI and SQIR value. This suggests that Hospital B provides higher-quality of services than hospital A.

**4.2 Sensitivity Analysis**

To see the effect of variation in the identified factors i.e. $F_i$ on the service quality index (SQI), sensitivity analysis is performed on the proposed model. This highlights the robustness of the model in real-life situations. Here, the percentage change in the value of SQI i.e. $QF_{1A}$ and $QF_{1B}$ is evaluated against a 10 percent increase in value of the diagonal elements $F_i$ of the equivalent matrix i.e. the major service factors of both the Hospitals A and B. The scores of each $F_i$ is increased by 10% at a time and the corresponding percentage change in the SQI value of both hospitals is obtained. The result of this analysis is shown in Table 4.3 and the calculations are shown in Appendix-III. A graph which illustrates the change in the percentage of the SQI when the factor scores of each $F_i$ is increased by 10 percent is depicted in Figure 4.2.

**Table 4.3** Sensitivity Analysis Results

| S. No | Quality Factor | % Increase in SQI Hospital A | % Increase in SQI Hospital B |
|---|---|---|---|
| 1 | Hospital Management and Administration | 0.59 | 0.56 |
| 2 | Healthcare Personnel Competencies | 0.31 | 0.41 |
| 3 | Support Facilities | 4.67 | 4.23 |
| 4 | Pre-Hospital and Hospital Ambience | 3.28 | 3.79 |
| 5 | Supply Chain Management | 0.85 | 0.91 |
| 6 | Treatment Process Quality | 0.66 | 1.32 |
| 7 | Information Technology Integration | 0.10 | 0.21 |

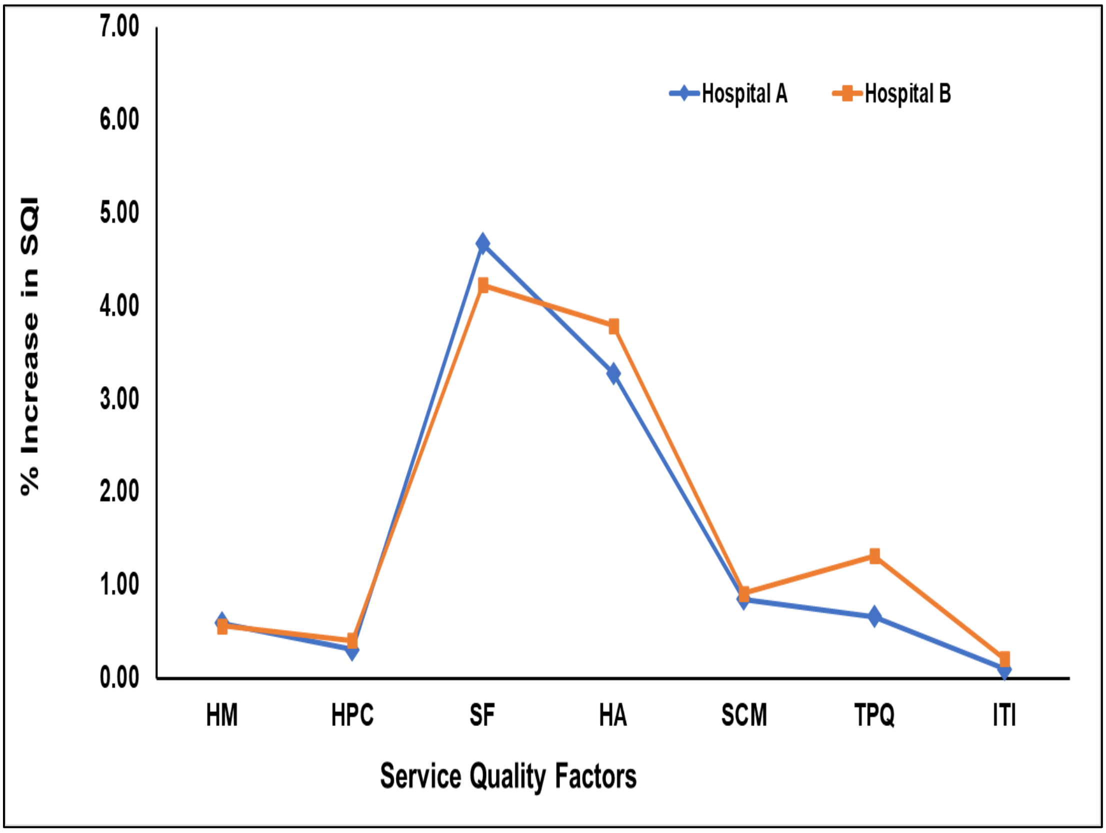


**Fig. 4.2** Variation of SQI with 10% increase in values of quality factors

Figure 4.2 illustrates that the SQI value is sensitive to the change in the values of service quality factors indicating that this proposed model is reliable. Further, it is less complex, easy to apply and analyse the results. From the sensitivity analysis, the service quality factors are arranged in decreasing order according to its effect on the SQI. For the Hospital A, these are Support Facilities (SF), Hospital Ambience (HA), supply chain management (SCM), Treatment process quality (TPQ), Hospital Management (HM), Information Technology Implementation (ITI). From Table 4.3, it is observed that the variation in SQI is proportional with variation in Hospital Support Facilities (SF). This was also seen with the Hospital Ambience (HA) as well. This simply means that a call for efforts to enhance support facilities and Hospital ambience will equally enhance the quality of the services delivered, which is needed. Therefore, Support Facilities and Hospital Ambience remain on the priority list of Hospitals that should focus on improving these areas.

# CHAPTER 5

## CONCLUSION, FUTURE SCOPE AND SOCIAL IMPACT

In conclusion, this project introduced a comprehensive methodology for the calculation of the service quality index (SQI) of Emergency Healthcare Systems based on the concept from James and James (2020), incorporating structural considerations through a digraph model supported by the Analytic Hierarchy Process (AHP) methodology. The AHP methodology played a crucial role in assigning weightages to various service quality factors, contributing to a more robust evaluation process. The integration of graph theory and matrix approaches facilitated the evolution of a service quality index. Some of the important remarks from this comprehensive research are listed as follows:

1. The validation of the proposed model was demonstrated through an illustrative case study, showcasing its applicability and effectiveness.
2. Subjectivity in giving values to service quality factors (Tables 3.2-3.8) was identified as a limitation.
3. To address this, the involvement of a team in the evaluation process, using established methodologies such as the Delphi method, could mitigate potential biases and enhance the objectivity of the results.
4. The proposed Service Quality Index (SQI) concept offers practical implications for various stakeholders. Hospital administrators can leverage the

methodology to assess the service quality of their emergency departments, while healthcare professionals can evaluate the performance of critical factors influencing emergency care. The SQI can serve as a valuable tool for identifying areas of improvement and implementing targeted measures to enhance emergency department service quality.

5. Looking ahead, the future work should include the integration of the proposed model with advanced technologies which has not been covered in this study. This integration could involve the use of data analytics, artificial intelligence, and real-time monitoring to provide a more dynamic and data-driven approach to evaluating and enhancing service quality in hospital emergency departments.

As the healthcare landscape continues to evolve, methodologies like this one play a vital role in ensuring the continuous improvement of service quality in emergency care settings, ultimately contributing to better patient outcomes and satisfaction.

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# APPENDIX-I

## AHP CALCULATION

Step 1: Calculate Column Sum of Pairwise-comparison matrix

Table I.1 Pair-wise comparison matrix

| | HM | HCP | SF | HA | SCM | TPQ | ITI |
|---|---|---|---|---|---|---|---|
| HM | 1 | 1 | 1 | 1 | 2 | 1 | 5 |
| HCP | 1 | 1 | 1 | 1 | 2 | 1 | 2 |
| SF | 1 | 1 | 1 | 2 | 2 | 0.5 | 2 |
| HA | 1 | 1 | 0.5 | 1 | 1 | 0.2 | 1 |
| SCM | 0.5 | 0.5 | 0.5 | 1 | 1 | 0.2 | 1 |
| TPQ | 1 | 1 | 2 | 5 | 5 | 1 | 5 |
| ITI | 0.2 | 0.5 | 0.5 | 1 | 1 | 0.2 | 1 |
| Sum | 5.70 | 6.00 | 6.50 | 12.00 | 14.00 | 4.10 | 17.00 |

Step 1: Divide each column entry by its sum

Table I.2

| | HM | HCP | SF | HA | SCM | TPQ | ITI |
|---|---|---|---|---|---|---|---|
| HM | 0.18 | 0.17 | 0.15 | 0.08 | 0.14 | 0.24 | 0.29 |
| HCP | 0.18 | 0.17 | 0.15 | 0.08 | 0.14 | 0.24 | 0.12 |
| SF | 0.18 | 0.17 | 0.15 | 0.17 | 0.14 | 0.12 | 0.12 |
| HA | 0.18 | 0.17 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 |
| SCM | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 |
| TPQ | 0.18 | 0.17 | 0.31 | 0.42 | 0.36 | 0.24 | 0.29 |
| ITI | 0.04 | 0.08 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 |

Step 2: Calculate Criteria weight by average of each row sum

Table I.3 Normalized Pair-wise Matrix

| | HM | HCP | SF | HA | SCM | TPQ | ITI | **criteria wt** |
|---|---|---|---|---|---|---|---|---|
| HM | 0.18 | 0.17 | 0.15 | 0.08 | 0.14 | 0.24 | 0.29 | **0.18** |
| HCP | 0.18 | 0.17 | 0.15 | 0.08 | 0.14 | 0.24 | 0.12 | **0.15** |
| SF | 0.18 | 0.17 | 0.15 | 0.17 | 0.14 | 0.12 | 0.12 | **0.15** |
| HA | 0.18 | 0.17 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 | **0.10** |
| SCM | 0.09 | 0.08 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 | **0.07** |
| TPQ | 0.18 | 0.17 | 0.31 | 0.42 | 0.36 | 0.24 | 0.29 | **0.28** |
| ITI | 0.04 | 0.08 | 0.08 | 0.08 | 0.07 | 0.05 | 0.06 | **0.07** |

Step 4: Multiply each column entry by its respective weight in initial pairwise matrix

Table I.4

| weight | 0.18 | 0.15 | 0.15 | 0.10 | 0.07 | 0.28 | 0.07 |
|---|---|---|---|---|---|---|---|
| | HM | HCP | SF | HA | SCM | TPQ | ITI |
| HM | 0.18 | 0.15 | 0.15 | 0.10 | 0.15 | 0.28 | 0.34 |
| HCP | 0.18 | 0.15 | 0.15 | 0.10 | 0.15 | 0.28 | 0.14 |
| SF | 0.18 | 0.15 | 0.15 | 0.19 | 0.15 | 0.14 | 0.14 |
| HA | 0.18 | 0.15 | 0.07 | 0.10 | 0.07 | 0.06 | 0.07 |
| SCM | 0.09 | 0.08 | 0.07 | 0.10 | 0.07 | 0.06 | 0.07 |
| TPQ | 0.18 | 0.15 | 0.30 | 0.49 | 0.36 | 0.28 | 0.34 |
| ITI | 0.04 | 0.08 | 0.07 | 0.10 | 0.07 | 0.06 | 0.07 |

Step 5: Calculate weighted sum value and it divide it by criteria weight

Table I.5

| | Weighted sum | Criteria Weight | Division |
|---|---|---|---|
| HM | 1.33 | 0.18 | 7.41 |
| HCP | 1.14 | 0.15 | 7.35 |
| SF | 1.10 | 0.15 | 7.34 |
| HA | 0.70 | 0.10 | 7.20 |
| SCM | 0.53 | 0.07 | 7.32 |
| TPQ | 2.09 | 0.28 | 7.46 |
| ITI | 0.48 | 0.07 | 7.34 |

Step6: Check for consistency

$\lambda$ max = 7.35

$\lambda$ max is the average value of the last column of Table I.5

Consistency index (CI) = 0.06786

Consistency Ratio(CR) = 0.050267 (<0.10)

As CR < 0.10, Hence Matrix is consistent.

$$CI = \frac{\lambda_{max} - n}{n-1}$$

**Consistency Ratio:**

| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.52 | .89 | 1.11 | 1.25 | 1.35 | 1.4 |

CR = CI / RI

•In practice, a **CR of 0.1** or below is considered acceptable.

**Fig. I.1** RI values for various “n”

# APPENDIX-II

## PERMANENT OF THE MATRIX EVALUATION

Permanent of the matrix is found using the tool (dCode, 2023). Screenshot for calculation of permanent of the matrix $QF_{1B}$ mentioned in section 4.1 is shown in Figure II.1 below:


**Fig II.1** Screenshot of Dcode website

# APPENDIX-III

## SENSITIVITY ANALYSIS CALCULATION

Table III.1 Hospital A sensitivity analysis

| variable | old value | 10% increased value | old permanent | new | % change |
|---|---|---|---|---|---|
| HM | 1.44 | 1.58 | 6416.84 | 6454.92 | 0.59 |
| HPC | 0.6 | 0.66 | 6416.84 | 6436.49 | 0.31 |
| SF | 1.35 | 1.49 | 6416.84 | 6716.61 | 4.67 |
| HA | 1.1 | 1.21 | 6416.84 | 6627.15 | 3.28 |
| SCM | 0.42 | 0.46 | 6416.84 | 6471.16 | 0.85 |
| TPQ | 0.84 | 0.92 | 6416.84 | 6459.22 | 0.66 |
| ITI | 0.49 | 0.54 | 6416.84 | 6423.13 | 0.10 |

Table III.2 Hospital B sensitivity analysis

| variable | old value | 10% increased value | old permanent | new | % change |
|---|---|---|---|---|---|
| HM | 1.44 | 1.58 | 6874.74 | 6913.42 | 0.56 |
| HPC | 0.75 | 0.83 | 6874.74 | 6902.71 | 0.41 |
| SF | 1.2 | 1.32 | 6874.74 | 7165.28 | 4.23 |
| HA | 1.3 | 1.43 | 6874.74 | 7135.57 | 3.79 |
| SCM | 0.35 | 0.39 | 6874.74 | 6937.59 | 0.91 |
| TPQ | 1.68 | 1.85 | 6874.74 | 6965.27 | 1.32 |
| ITI | 0.56 | 0.62 | 6874.74 | 6889.13 | 0.21 |

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21-May-2024

Dear Author(s)

It is a pleasure to inform you that your manuscript titled DEVELOPMENT OF A FRAMEWORK FOR EVALUATION OF QUALITY OF EMERGENCY CARE SERVICES OF INDIAN HOSPITALS (IJQRM-04-2024-0125) has passed initial screening and is now awaiting reviewer selection. The manuscript was submitted by Dr. Girish Kumar with you listed as a co-author. As you are listed as a co-author please log in to https://mc.manuscriptcentral.com/ijqrm and check that your account details are complete and correct, these details will be used should the paper be accepted for publication.

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# BRIEF PROFILE

My name is Kumar Amit. I am from Patna, Bihar. I have completed my Bachelor of Engineering (B.E.) in Mechanical Engineering from RV College of Engineering, Bengaluru with CGPA of 8.93. At present, I am pursuing Master of Technology (MTech) in Industrial Engineering and Management (IEM) from Delhi Technological University, New Delhi. I am currently working on a project topic "Development of a Framework for Evaluation of Quality of Emergency Care Services of Indian Hospitals".

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**Position of Responsibility**

Teaching Assistant (TA) duty in DTU includes assisting the faculty in proper management and conduct of experiments, record correction, viva, quiz, etc. of more than 400 BTech students in various Labs such as Theory of Machines, RAC, Workshop, Power Plant, Energy etc. from August 2022 till May 2024.

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| **Remarks :** | MTech Thesis submission fee |
| **Notification 1:** | Late Registration fee Rs.50 per day, Hostel Room Rent for internship Rs.1000 per month, Hostel Cooler Rent Rs.1000 per year, I card Rs.200, Character certificate Rs.200, Migration certificate Rs.200, Bonafide certificate Rs.200, Special certificate Rs.500, Provisional certificate Rs.200, Duplicate Mark sheet Rs.500, Training Diary Rs.70 |
| **Notification 2:** | Fee Structure Rs.200, Admit Card Rs.50. Transcript fee and other fee rates has to be confirmed from the Academic Cell prior to remit the fees online by the student. |

# Delhi Technological University

**(Formerly Delhi College of Engineering)**

**Regular Result Notification**

Visit - http://exam.dtu.ac.in

THE RESULT OF THE CANDIDATE WHO APPEARED IN THE FOLLOWING EXAMINATION HELD IN MAY , 2023 IS DECLARED AS UNDER : -

Notification No. 1566

**Program : Master of Technology**

**Sem : II**

**Branch : Industrial Engineering and Management**

TC : Total Credits    DT : Detained    AB : Absent    RL : Result Later    RW : Result Withdrawn

IEM502 : OPERATIONS RESEARCH
IEM504 : SUPPLY CHAIN MANAGEMENT
IEM5404 : INDUSTRY 4.0 & SMART MANUFACTURING
IEM5304 : International Logistics and Warehouse Managment
IEM5210 : Contemporary Issues in Industrial Engineering and Managment

| Sr.No | Name | Roll No. | IEM502 | IEM504 | IEM5404 | IEM5304 | IEM5210 | TC | SGPA | Papers Failed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Credits | 4 | 4 | 4 | 3 | 2 | | | |
| 1 | ADITYA SAXENA | 2K22/IEM/01 | F | F | F | F | F | 0 | 0.00 | IEM502IEM504, IEM5404, IEM5304, IEM5210, |
| 2 | AMAN MAAN | 2K22/IEM/02 | O | B+ | A+ | A | O | 17 | 8.71 | |
| 3 | ANIKET MODI | 2K22/IEM/03 | O | B+ | A | A | A | 17 | 8.24 | |
| 4 | ASHISH MALHOTRA | 2K22/IEM/04 | B+ | B | B | B | B | 17 | 6.24 | |
| 5 | HAMISH ALI | 2K22/IEM/05 | A | C | A | B+ | A+ | 17 | 7.24 | |
| 6 | KAMALDEEP SAHU | 2K22/IEM/06 | A+ | B+ | O | A+ | A+ | 17 | 8.76 | |
| 7 | KUMAR AMIT | 2K22/IEM/07 | O | O | O | O | O | 17 | 10.00 | |
| 8 | LAKSHYA SAINI | 2K22/IEM/08 | A+ | A | A | A+ | A+ | 17 | 8.53 | |
| 9 | SAMIR KUMAR | 2K22/IEM/09 | A+ | A | O | O | A+ | 17 | 9.18 | |
| 10 | SHEETAL SHARMA | 2K22/IEM/10 | A | A | O | A+ | A | 17 | 8.65 | |
| 11 | SHUBHAM SAURABH | 2K22/IEM/11 | A+ | B+ | A | A | A | 17 | 8.00 | |
| 12 | SUBADEEP DAS | 2K22/IEM/12 | O | B+ | A+ | A+ | A | 17 | 8.65 | |
| 13 | VATAN SINGH | 2K22/IEM/13 | A+ | A+ | A+ | A+ | A+ | 17 | 9.00 | |

**Any discrepancy in the result in r/o name/roll no/registration/marks/grades/course code/title should be brought to the notice of Controller of Examination/OIC B.tech(Eve.) within 15 days of declaration of result , in the prescribed proforma.**

Date : 20/06/2023

Digitally Signed by Madhukar Cherukuri , OIC (Results)

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Controller Of Examination

# Delhi Technological University

**(Formerly Delhi College of Engineering)**

**Regular Result Notification**

Visit - http://exam.dtu.ac.in

THE RESULT OF THE CANDIDATE WHO APPEARED IN THE FOLLOWING EXAMINATION HELD IN NOVEMBER , 2022 IS DECLARED AS UNDER : -

Notification No. 1510

**Program : Master of Technology**

**Sem : I**

**Branch : Industrial Engineering and Management**

TC : Total Credits | DT : Detained | AB : Absent | RL : Result Later | RW : Result Withdrawn

IEM501 : Data Analytics
IEM503 : Production & Operation Management
IEM5205 : Principles of Managment
IEM5305 : Total Quality Management
IEM5407 : Product Design & Development

| Sr.No | Name | Roll No. | IEM501 | IEM503 | IEM5205 | IEM5305 | IEM5407 | TC | SGPA | Papers Failed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Credits | 4 | 4 | 2 | 3 | 4 | | | |
| 1 | ADITYA SAXENA | 2K22/IEM/01 | B | F | A | B | B | 13 | 4.82 | IEM503, |
| 2 | AMAN MAAN | 2K22/IEM/02 | A | P | A+ | A | A+ | 17 | 7.41 | |
| 3 | ANIKET MODI | 2K22/IEM/03 | A | B | A | A | A+ | 17 | 7.76 | |
| 4 | ASHISH MALHOTRA | 2K22/IEM/04 | B | C | B+ | C | A | 17 | 6.18 | |
| 5 | HAMISH ALI | 2K22/IEM/05 | B | P | B+ | B | A | 17 | 6.12 | |
| 6 | KAMALDEEP SAHU | 2K22/IEM/06 | A | C | O | A+ | A+ | 17 | 7.94 | |
| 7 | KUMAR AMIT | 2K22/IEM/07 | O | A+ | O | O | O | 17 | 9.76 | |
| 8 | LAKSHYA SAINI | 2K22/IEM/08 | O | A | A+ | A+ | A+ | 17 | 9.00 | |
| 9 | SAMIR KUMAR | 2K22/IEM/09 | B+ | B+ | A+ | A+ | A+ | 17 | 8.06 | |
| 10 | SHEETAL SHARMA | 2K22/IEM/10 | A+ | B | A | B | A+ | 17 | 7.65 | |
| 11 | SHUBHAM SAURABH | 2K22/IEM/11 | A+ | B | A | A | A | 17 | 7.76 | |
| 12 | SUBADEEP DAS | 2K22/IEM/12 | A | B+ | A+ | A | O | 17 | 8.35 | |
| 13 | VATAN SINGH | 2K22/IEM/13 | O | A | A+ | O | O | 17 | 9.41 | |

**Any discrepancy in the result in r/o name/roll no/registration/marks/grades/course code/title should be brought to the notice of Controller of Examination/OIC B.tech(Eve.) within 15 days of declaration of result , in the prescribed proforma.**

Date : 11/01/2023

Digitally Signed by Madhukar Cherukuri , OIC (Results)
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Controller Of Examination

# Delhi Technological University
(Formerly Delhi College of Engineering)

**THE RESULT OF THE CANDIDATE WHO APPEARED IN THE FOLLOWING EXAMINATION HELD IN NOV 2023 IS DECLARED AS UNDER:-**

## Master of Technology(Industrial Engineering and Management), III-SEMESTER

**Result Declaration Date : 04-03-2024** **Notification No: 1660**

IEM601 : MAJOR PROJECT I IEM6201 : E- Commerce IEM6303 : Knowledge Management IEM6405 : Advanced Operation Research

| Sr.No | Roll No. | Name of Student | IEM601 | IEM6201 | IEM6303 | IEM6405 | SGPA | TC | Failed Courses |
|---|---|---|---|---|---|---|---|---|---|
| | | | 3.00 | 2.00 | 3.00 | 4.00 | | | |
| 1 | 2K22/IEM/02 | AMAN MAAN | B+ | O | A | A+ | 8.42 | 12 | |
| 2 | 2K22/IEM/03 | ANIKET MODI | B+ | A | B+ | A | 7.5 | 12 | |
| 3 | 2K22/IEM/04 | ASHISH MALHOTRA | B+ | A | C | B | 6.33 | 12 | |
| 4 | 2K22/IEM/05 | HAMISH ALI | B+ | A+ | B | B+ | 7.08 | 12 | |
| 5 | 2K22/IEM/06 | KAMALDEEP SAHU | B+ | A+ | B | A+ | 7.75 | 12 | |
| 6 | 2K22/IEM/07 | KUMAR AMIT | A+ | O | O | O | 9.75 | 12 | |
| 7 | 2K22/IEM/08 | LAKSHYA SAINI | A+ | A+ | B+ | A+ | 8.5 | 12 | |
| 8 | 2K22/IEM/09 | SAMIR KUMAR | B+ | A+ | A | A | 7.92 | 12 | |
| 9 | 2K22/IEM/10 | SHEETAL SHARMA | B+ | A+ | B | A | 7.42 | 12 | |
| 10 | 2K22/IEM/11 | SHUBHAM SAURABH | B+ | A | B | A | 7.25 | 12 | |
| 11 | 2K22/IEM/12 | SUBADEEP DAS | A | A+ | B | A | 7.67 | 12 | |
| 12 | 2K22/IEM/13 | VATAN SINGH | A | O | A | A+ | 8.67 | 12 | |

**OIC (Results)** **Controller of Examination**

**Note:**Any discrepancy in the result in r/o name/roll no/registration/marks/grades/course code/title should be brought to the notice of Controller of Examination/OIC(Results) within 15 days of declaration of result in the prescribed proforma.