Original Article

Managerial and educational barriers to the implementation of preventive maintenance systems for critical hospital equipment and facilities

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Abstract

Background: Critical hospital equipment is essential for safe, high-quality healthcare, relying on effective preventive maintenance systems. Beyond management, the knowledge and training of maintenance staff significantly impact system effectiveness. This study aimed to identify the managerial and educational barriers to implementing a preventive maintenance system in Baath Hospital of Gachsaran and propose targeted improvement strategies.

Methods: A mixed-methods sequential exploratory design was used in 2024. The qualitative phase involved semi-structured interviews with 14 experts in medical equipment and hospital facilities, analyzed through thematic content analysis. Findings informed a researcher-made questionnaire distributed to 102 staff members in the quantitative phase. The questionnaire assessed managerial, organizational, technical, financial, infrastructural, and educational factors affecting maintenance implementation.

Results: Barriers were categorized into six main dimensions: managerial, organizational, human resources, technical, financial, and infrastructural, with educational issues emerging as a critical cross-cutting factor. Financial barriers ranked highest (mean score: 4.08), followed by human resource and managerial barriers. Key educational challenges included insufficient training programs, limited staff technical knowledge, and a lack of structured learning systems. A significant positive relationship was observed between several dimensions, most notably between managerial and human resource barriers.

Conclusion: The primary barriers include financial constraints, a shortage of skilled human resources, inadequate training, and weak maintenance planning. Strengthening managerial structures, developing continuous education programs, and improving technical competencies are crucial for enhancing maintenance effectiveness and, consequently, the quality and safety of healthcare services.

Keywords: Crew Resource Management, Healthcare; Equipment and Supplies; Maintenance; prevention and control [Subheading]; Staff Development.

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Introduction

The growing integration of sophisticated medical technologies and complex infrastructural systems within healthcare facilities has underscored the critical importance of robust maintenance frameworks for uninterrupted health service delivery. As pivotal institutions in any health system, hospitals

fundamentally rely on the consistent and reliable operation of clinical apparatus, utility networks, and support infrastructure to render care that is both safe and of high standard. Any disruption or failure within these assets can precipitate severe repercussions for patient well-being, care quality, and the operational continuity of the institution itself (1, 2).

Among various upkeep methodologies, proactive maintenance approaches have gained considerable traction in hospital asset governance, focusing on averting breakdowns, curtailing unscheduled service interruptions, and prolonging the functional lifespan of technical resources (3-5). This type of maintenance encompasses a series of scheduled interventions executed prior to any malfunction, designed to sustain peak equipment performance. Evidence from the literature demonstrates that the successful deployment of such proactive programs can lower emergency repair expenditures, bolster device dependability, and elevate overall organizational efficiency (6-8). Within the hospital setting, these considerations are magnified, since the failure of vital equipment not only halts therapeutic workflows but may also imperil the health of both patients and personnel (9, 10).

Beyond administrative oversight and technical workflows, the expertise, practical skills, and ongoing development of the workforce tasked with running and maintaining these assets constitute indispensable pillars for the success of proactive upkeep strategies. Structured learning initiatives, vocational training, and capacity-strengthening efforts can elevate workforce competencies, foster correct device handling, and reinforce compliance with maintenance standards across healthcare organizations.

Notwithstanding the recognized value of proactive maintenance, numerous medical establishments in low-resource settings grapple with formidable obstacles in instituting and sustaining such programs effectively. Constraints in fiscal allocations, a deficit of qualified technical staff, deficiencies in equipment governance, an absence of methodical planning, and inadequate utilization of suitable information platforms represent core hindrances that can erode program success (11, 12). Frequently, scarce developmental opportunities, narrow technical expertise among employees, and the lack of formalized instructional frameworks for asset stewardship further compound these difficulties. Studies suggest that failing to adopt a cohesive managerial and capacity-building orientation toward maintenance leads to a higher incidence of unforeseen device failures, escalated running costs, and diminished care quality (13). A meticulous mapping of these impediments, coupled with the formulation of targeted administrative and educational interventions, can be instrumental in bolstering the execution of proactive maintenance within hospitals. Such a perspective equips decision-makers to streamline upkeep operations, judiciously distribute resources, fortify governance architectures, and enhance the professional capabilities of personnel through sustained learning and development, thereby augmenting the trustworthiness of hospital equipment and essential infrastructure (14).

This study was conducted to identify and analyze the managerial and educational barriers to implementing preventive maintenance systems for critical equipment and infrastructure at Baset Hospital in Gachsaran and to propose management and training strategies for improvement.

Methods

Research Design

A two-phase, exploratory sequential design combining qualitative and quantitative methodologies was utilized for this research. During the opening qualitative component, the focus was placed on eliciting and cataloging the impediments to

deploying preventive upkeep frameworks for vital clinical equipment and facility systems. The subsequent quantitative component then proceeded to systematically measure and scrutinize these challenges, culminating in the development of pragmatic, management-oriented solutions designed to reinforce system-wide adoption and effectiveness.

Study Population

Participants were drawn from among those who, in 2021, held responsibilities related to the operation, maintenance, or governance of clinical equipment and facility systems at Baset Hospital in Gachsaran. This included executive managers, supervisors of technical and engineering units, biomedical equipment specialists, repair and upkeep technicians, and additional personnel engaged in equipment-related workflows, whether in a direct or supportive capacity.

Sample Size and Sampling Method

For the qualitative strand, a purposive sampling strategy was employed to recruit participants. In-depth, semi-structured interviews were carried out with seasoned professionals and staff possessing hands-on expertise in the administration and upkeep of medical equipment. Data collection proceeded iteratively until the point of thematic saturation, at which no novel insights emerged. Ultimately, between 12 and 15 individuals took part in this stage of the study.

In the quantitative strand, the required sample size was established based on the total number of personnel associated with equipment and facility operations, yielding a participant range of roughly 80 to 120 hospital employees. To ensure fair and proportional representation from all relevant organizational units, a stratified random sampling technique was applied, with strata defined according to departmental affiliation.

Inclusion and Exclusion Criteria

Eligibility for participation required a minimum of one year of employment at the hospital, direct or indirect engagement with medical devices, facility systems, or upkeep activities, and a stated willingness to take part in the research. Individuals were excluded from the study if they submitted incomplete survey forms, chose to withdraw at any point during the process, or lacked adequate familiarity or practical exposure to hospital equipment and infrastructural operations.

Study Variables

The primary variable of interest was the barriers to implementing preventive maintenance systems for critical hospital equipment and infrastructure. These barriers were assessed across six dimensions: managerial, organizational, human resources, technical, financial, and infrastructural factors. Demographic variables such as age, gender, education level, work experience, and organizational position were also examined as contextual factors.

Data Collection Instruments

During the qualitative stage, data gathering was facilitated through a semi-structured interview protocol developed to uncover the principal obstacles hindering the adoption of preventive maintenance practices. Prior to each interview, informed consent was secured from participants, and all sessions were audio-recorded and subsequently transcribed verbatim for analytical purposes.

In the quantitative stage, a questionnaire constructed by the research team served as the primary data collection tool. Its development was guided by insights drawn from the earlier qualitative phase and a review of relevant scholarly literature. The instrument consisted of two parts: a section capturing demographic characteristics and a section measuring perceived barriers to the deployment of preventive maintenance

systems. Responses to the barrier items were captured using a five-point Likert-type scale, with anchors ranging from "strongly disagree" to "strongly agree." The tool's content validity was verified through expert review by specialists in healthcare administration and medical equipment engineering, while its internal consistency was evaluated using Cronbach's alpha coefficient.

Research Procedure

The study was conducted in two phases. In the first phase, semi-structured interviews with experts and knowledgeable staff identified key barriers to preventive maintenance system implementation. Following qualitative analysis and extraction of major themes, a questionnaire was developed based on these findings.

In the second phase, the questionnaire was distributed to the selected hospital staff. After data collection, the responses were entered into statistical software for analysis. Based on the results and expert input, managerial strategies were proposed to improve the implementation of preventive maintenance systems.

Statistical Analysis

Statistical treatment of the quantitative data was performed using SPSS software, version 26. To provide an overview of the dataset, descriptive measures—namely frequencies, percentages, mean scores, and standard deviations—were computed. For examining associations and differences among variables, a set of inferential statistical tests was employed, including independent-samples t-tests, one-way analysis of variance (ANOVA), and Pearson correlation coefficients. Furthermore, exploratory factor analysis was conducted to uncover the underlying dimensional structure of the identified barriers.

The qualitative data derived from interview transcripts were subjected to thematic content analysis, a systematic process through which recurring patterns, principal themes, and conceptual categories were distilled and organized.

Ethical Considerations

Ethical clearance for this research was granted by the Ethics Committee of Islamic Azad University, Shahr-e Kord Branch, under approval code IR.IAU.SHK.REC.1404.022. Prior to any data gathering, written informed consent was secured from every participant. Throughout the study, the anonymity and confidentiality of all collected information were strictly upheld, and the data were utilized exclusively for the purposes of this investigation.

Results

A total of 102 completed questionnaires were analyzed. In the qualitative phase, 14 experts and hospital staff involved with medical equipment, facilities, and maintenance participated in semi-structured interviews. The qualitative analysis identified a set of barriers across six main dimensions: managerial, organizational, human resources, technical, financial, and infrastructural. These dimensions were subsequently evaluated in the quantitative phase.

The demographic profile of the participants, summarized in Table 1, reveals that men constituted the majority of the sample at 60.8%. In terms of age distribution, individuals aged between 30 and 40 years represented the largest subgroup, accounting for 45.1% of respondents. With respect to educational attainment, a bachelor's degree was the most commonly held qualification, reported by 53.9% of the participants. As for professional tenure, the predominant category was 5 to 10 years of work experience, encompassing 36.3% of the staff. This pattern suggests a workforce characterized by a moderate level of practical familiarity with the operation and oversight of hospital apparatus and infrastructural systems.

Table 1. Demographic Characteristics of Study Participants (Frequency Distribution)

Variable	Category	Frequency	Percentage
Gender	Male	62	60.8
	Female	40	39.2
Age	Under 30 years	18	17.6
	30–40 years	46	45.1
	41–50 years	26	25.5
	Over 50 years	12	11.8
Education	Associate degree	14	13.7
	Bachelor's degree	55	53.9
	Master's degree or higher	33	32.4
Work Experience	Less than 5 years	21	20.6
	5–10 years	37	36.3
	11–15 years	25	24.5
	More than 15 years	19	18.6

Table 2. Mean and Standard Deviation of the Dimensions of Barriers to Implementing Preventive Maintenance Systems

Dimension of Barriers	Mean	SD
Managerial Barriers	3.87	0.71
Organizational Barriers	3.65	0.68
Human Resources Barriers	3.92	0.73
Technical Barriers	3.54	0.64
Financial Barriers	4.08	0.69
Infrastructural Barriers	3.61	0.66

The results in Table 2 show that financial barriers had the highest mean score (4.08), followed by human resources barriers (3.92) and managerial barriers (3.87). These findings indicate that financial limitations, a shortage of skilled personnel, and weaknesses in management policies are among the most significant challenges to implementing preventive maintenance systems in the hospital studied.

Table 3. Exploratory Factor Analysis Results for Identifying Barrier Dimensions

Factor	Percentage of Variance Explained	Eigenvalue
Managerial Factor	21.4%	4.21
Human Resources Factor	18.7%	3.62
Financial Factor	15.3%	3.11
Organizational Factor	13.2%	2.74
Infrastructural Factor	10.1%	2.09
Technical Factor	9.4%	1.86

Factor analysis results showed that six main factors collectively accounted for approximately 88.1% of the total variance in the barriers to implementing preventive maintenance systems. Among these, the managerial factor, which had the highest eigenvalue and explained variance, emerged as the most critical dimension identified in this study Table 3.

Table 4. Comparison of Mean Scores of Barriers to Implementing Preventive Maintenance Systems by Educational Level

Education Level	Mean	Standard Deviation	P-value
Associate Degree	3.55	0.58	0.031
Bachelor's Degree	3.74	0.63	
Master's Degree or Higher	3.96	0.66	

The results of the one-way ANOVA indicated a significant difference in perceived barriers across educational levels ($p = 0.05$). Individuals with higher education reported greater awareness of barriers to implementing preventive maintenance systems. This finding may reflect their increased knowledge of managerial and technical processes involved in equipment maintenance Table 4.

Table 5. Correlations among the Various Dimensions of Barriers to Implementing Preventive Maintenance Systems

Variable	Managerial	Organizational	Human Resources	Financial
Managerial	1	—	—	—
Organizational	0.54	1	—	—
Human Resources	0.61	0.48	1	—
Financial	0.57	0.52	0.59	1

Pearson correlation analysis revealed positive and significant relationships among the various dimensions of barriers to implementing preventive maintenance systems. The strongest correlation was observed between managerial and human resources barriers (r = 0.61), indicating that weaknesses in management policies can directly impact personnel-related issues and technical capabilities Table 5.

Table 6. Ranking of Barriers to Implementing Preventive Maintenance Systems Based on Mean Scores

Rank	Dimension of Barriers	Mean
1	Financial	4.08
2	Human Resources	3.92
3	Managerial	3.87
4	Organizational	3.65
5	Infrastructural	3.61
6	Technical	3.54

The results of Table 6 show that financial barriers were ranked highest. Respondents identified critical issues, including insufficient budgets for equipment maintenance, limited access to spare parts, and the lack of adequate investment plans. Human resources and managerial barriers followed, reflecting challenges such as a shortage of skilled personnel, inadequate staff training, and weaknesses in managerial planning and supervision. These findings indicate that improving the implementation of preventive maintenance systems in hospitals requires simultaneous attention to financial, human resources, and managerial dimensions.

Discussion

The present investigation set out to uncover and examine the obstacles impeding the deployment of preventive upkeep frameworks for vital equipment and infrastructure at Baset Hospital in Gachsaran, alongside formulating administrative remedies to strengthen such systems. Proactive maintenance constitutes a fundamental pillar of physical asset stewardship within healthcare organizations, playing a pivotal role in safeguarding patient well-being, curtailing unforeseen device breakdowns, and elevating the overall standard of care delivery. Yet, the methodical and all-encompassing execution of these programs encounters substantial hurdles across numerous medical facilities, most notably in resource-limited settings. The outcomes of this research point to fiscal, workforce, and governance-related impediments as the foremost hindrances to successful implementation. These challenges can directly erode the effectiveness of upkeep initiatives and the operational throughput of hospital apparatus.

According to the results, monetary constraints emerged as the top-ranked obstacle, registering the highest average score. Participants underscored several pressing issues, among them restricted fiscal allotments for servicing operations, difficulties in the timely procurement of replacement components, elevated expenditures associated with specialized repairs, and dependency on imported parts for certain devices. Such circumstances obstruct the full-scale adoption of preventive protocols, frequently giving rise to a reactive maintenance posture wherein corrective actions are undertaken solely after malfunctions manifest. This pattern can escalate long-range expenditures, curtail equipment longevity, and interfere with the continuity of patient care services.

These observations resonate with the work of Taghipour et al., who examined the prioritization of clinical devices for upkeep

scheduling. Their study concluded that budgetary limitations represent a primary deterrent to the productive execution of maintenance schemes in healthcare environments, and that inadequate funding for servicing can prompt the deferral or outright elimination of scheduled preventive measures (6). Likewise, Saenagri et al. stressed that scarce financial means, deficient budgetary planning, and underinvestment in medical device governance pose major difficulties for health systems, especially within developing nations. In many hospital settings, a considerable share of apparatus functions at diminished capacity or is rendered inoperative entirely owing to a lack of funds for servicing and refurbishment (15).

In the current study, workforce-associated hurdles were recognized as the second most prominent challenge. Chief concerns included a scarcity of qualified technicians in the domains of medical equipment and maintenance, inadequate personnel instruction, and the absence of systematic, ongoing developmental initiatives. These findings are in harmony with the research of Roda et al., which stressed that the potency of upkeep systems is profoundly contingent upon the availability of well-trained and specialized staff (16). In a similar vein, Lee et al. observed that a deficiency in technical proficiency among workers can considerably weaken the viability of proactive maintenance endeavors (17).

Governance-related elements likewise surfaced as a vital category of obstacles. Respondents pointed to deficiencies in servicing schedules, the want of explicit administrative directives, and insufficient mechanisms for performance oversight and appraisal (18). These results correspond with the assertions of Selcuk, who accentuated the significance of structured planning and regulatory control within maintenance frameworks and remarked that the absence of a fitting managerial architecture can precipitate a heightened frequency of unscheduled equipment outages and inflated operational outlays (19).

Furthermore, correlation testing uncovered a meaningful linkage between managerial and human resource factors, indicating that sound administrative policies are instrumental in bolstering workforce capabilities and augmenting the holistic performance of upkeep operations. This outcome aligns with the scholarship of Ebekozien, which emphasizes that efficacious maintenance governance necessitates the harmonious integration of personnel, technology, and institutional planning (20).

Organizational and infrastructural factors were also found to influence the implementation of preventive maintenance programs, although their impact was somewhat lower than that of financial and human resource barriers. In many hospitals, the absence of a well-defined organizational structure for maintenance management, weak planning and supervision of maintenance activities, lack of standard operating procedures, and underutilization of maintenance management information systems hinder effective implementation. Technical infrastructure limitations such as the absence of computerized maintenance management systems, inadequate facilities for monitoring equipment conditions, and poor documentation practices further reduce the efficiency of these programs (21).

These findings suggest that even when financial resources are sufficient, the absence of strong organizational and infrastructural foundations can compromise the effectiveness of preventive maintenance programs. Successful implementation, therefore, requires coherent managerial structures, clearly defined processes for planning and monitoring maintenance activities, and adequate technical infrastructure to support information

management and decision-making. In this context, fostering coordination among organizational units, establishing standard operating procedures, and deploying modern maintenance management systems can substantially enhance program performance.

Overall, the results of this study indicate that implementing successful preventive maintenance systems in hospitals requires a comprehensive, multidimensional approach. Such an approach should ensure not only adequate financial resources but also the development and empowerment of human resources, improvement of managerial structures, optimization of organizational processes, and strengthening of technical and technological infrastructure. This integrated strategy can enable effective preventive maintenance programs, ultimately improving the reliability and safety of medical equipment (22).

Limitations

Notwithstanding the meticulous efforts invested in conducting this investigation, several constraints warrant consideration when appraising the results. To begin with, the study was confined to a single medical institution—Be'sat Hospital in Gachsaran—which inherently restricts the transferability of the conclusions to other hospitals or healthcare settings. Disparities in administrative frameworks, fiscal capacities, technical proficiencies, and contextual organizational circumstances may shape the execution of preventive maintenance systems in different environments. Additionally, the quantitative component drew upon self-reported accounts from respondents, leaving the data potentially susceptible to subjective biases or individual perceptual filters. A further limitation relates to the condensed duration of the research and the restricted availability of certain specialists in medical equipment and hospital infrastructure, which may have curtailed the depth and scope of expert involvement during the qualitative stage. These considerations should be borne in mind, as they hold implications for both the comprehensiveness and the interpretive lens applied to the study's outcomes.

Recommendations

Drawing upon the evidence gathered in this research, it is advisable for subsequent investigations to probe the obstacles hindering preventive maintenance deployment across a broader spectrum of healthcare institutions and at varying tiers of the health system. Undertaking such multi-site inquiries would facilitate richer cross-institutional comparisons and strengthen the external validity of the findings. Moreover, the application of more sophisticated analytical approaches—such as structural equation modeling or multi-criteria decision-analysis techniques—could yield a more nuanced understanding of the interplay among variables shaping the execution of upkeep programs.

From an applied perspective, hospital leadership is encouraged to bolster targeted professional development initiatives for both technical personnel and administrative cadres, establish methodical frameworks for scheduling and overseeing maintenance activities, and embrace computerized maintenance management systems (CMMS) to streamline the implementation of proactive upkeep practices. Additionally, augmenting earmarked funds for medical device servicing and channeling investments into the enhancement of technical infrastructure can serve as pivotal levers in elevating the functionality, dependability, and service life of essential hospital equipment.

Conclusion

What emerges from this study is that the successful rollout of proactive maintenance frameworks for critical clinical apparatus and facility systems encounters multiple hindrances. The most pronounced obstacles identified encompass budgetary shortfalls, a deficit of competent human resources, and

gaps in both the administrative oversight and systematic planning of servicing activities. Overcoming these challenges requires effective managerial interventions, such as increasing investment in equipment maintenance, developing comprehensive staff training programs, implementing structured maintenance management systems, and utilizing information systems to support equipment oversight. In summary, reinforcing managerial and organizational structures, alongside providing adequate resources, can substantially enhance the effectiveness of preventive maintenance systems. These improvements are expected to increase equipment reliability, minimize unexpected breakdowns, and ultimately improve the quality of healthcare services in hospitals.

Authors' contribution

Mahnaz Shafakhah and Mahdiye Zarepour developed the study concept and design. Lida Gholizadeh and Mahnaz Shafakhah acquired the data. Mahdiye Zarepour and Lida Gholizadeh analyzed and interpreted the data, and wrote the first draft of the manuscript. All authors contributed to the intellectual content, manuscript editing and read and approved the final manuscript.

Informed consent

Questionnaires were filled with the participants' satisfaction and written consent was obtained from the participants in this study.

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Conflict of interest

The authors declare that they have no conflict of interests.

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