

Enhancing Operational Efficiency in Hospital Maintenance Units: Lessons learned from the National Hospital of Sri Lanka

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Abstract

Effective management of hospital maintenance units is crucial for the upkeep and repair of medical and general equipment, ensuring uninterrupted, high-quality healthcare services. The National Hospital of Sri Lanka (NHSL), established in the 1970s, relies on a vast array of equipment, making the efficiency of its maintenance unit vital. This study examines strategies to enhance operational efficiency in hospital maintenance units, drawing lessons from NHSL. Objectives included evaluating the efficiency of NHSL's current maintenance processes, identifying areas for improvement, and developing recommendations for enhancing the unit. A qualitative approach was employed, involving observation visits and semi-structured key informant interviews with administrative and technical officers, ward in-charges, storekeeper, maintenance workers, and public works department workers. Data were coded and analyzed using NVivo software to identify common themes and challenges. Findings revealed several critical issues: persistent delays in repairs and frequent equipment breakdowns, a lack of skilled staff, gaps in technical and supervisory skills, delays in recruitment, poor communication, and lack of recognition for maintenance staff contributions, inadequate technical training opportunities, limited repair and storage space, insufficient sanitary facilities, and delays in spare parts supply. The study underscores the need for strategic improvements in NHSL's maintenance unit. Key recommendations include conducting training programs, establishing a central maintenance unit, providing new machinery and tools, regular vocational training, improving communication channels, and enhancing sanitary facilities. Addressing these challenges can significantly improve the maintenance unit's operational efficiency and the overall quality of healthcare services at NHSL.

Keywords: Effective management, Maintenance units, Medical devices.

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Introduction

The management of medical equipment are a complex and strategic function that plays a crucial role in the successful delivery of patient care (Ministry of Health Malaysia, 2016), ensuring that medical equipment is operational, safe, and in good working condition is a critical responsibility of the medical equipment managers and maintenance staff. Timely and proper maintenance can also prolong the lifespan of the equipment (Malkin, 2007).

The National Hospital of Sri Lanka (NHSL) is the largest teaching hospital in the country, situated in Colombo and spanning a land area of 32 acres. Comprising approximately 400 units, including 85 wards and various other units, NHSL delivers essential healthcare services to patients and serves as a referral center for patients from other hospitals, offering a broad spectrum of sub-specialties. The hospital has a total bed capacity of 3,269, with an average of 671 daily admissions and a nightly average census of approximately 2,525

To provide efficient healthcare services, NHSL utilizes a wide array of general and medical devices, including surgical, medical, orthopedic, and general equipment. The responsibility for the maintenance and repair of these general equipment items lies with the NHSL maintenance unit. This unit also manages the supply lines of water, minor electrical and electronic repairs, iron and carpentry work, welding, painting, masonry, and plumbing.

The maintenance unit of NHSL, established in the 1970s with just two carpenters, has since expanded its scope and staff to encompass various areas of maintenance and repair. Currently, the maintenance unit is divided into five workshops, each located in different areas of the hospital premises. The five locations are:

- Unit one: Ground floor of Neurotrauma building with nine workers
- Unit two: Third medical building with nine workers
- Unit three and four: Old nurses quarters with ten and two workers respectively
- Unit five: Second floor of the Epilepsy building with five workers

Administrative supervision of the maintenance unit is overseen by the administrative officer (AO) of the hospital, while technical supervision is provided by the technical officer. Additionally, the Public Works Department which is an department of the government that conducts equipment maintenance activities for the government departments, operates a separate workshop that handles repairs of specific items such as beds, trollies, carts, and saline stands. Although this unit used to operate seven days a week, its services are now limited to two days, specifically Saturday and Sunday. Furthermore, a community service organization for the blind contributes to the hospital's efforts by providing re-weaving services for cain chairs, time to time as requested by the hospital management.

This study aimed to investigate the challenges faced by the National Hospital of Sri Lanka's (NHSL) maintenance unit and identify potential strategies to enhance its operational efficiency

Justification

When a general item in a ward or unit breaks down or an infrastructural problem arises, the person in charge of the respective unit informs the AO-4 through a correspondent book. The administrative officer in consultation with the technical officer directs the complaint either to the maintenance unit or to the public works department workshop. If the repair is unable to be handled by these units AO and the technical officer with approval of the director recommend outsourcing the repair to one of the registered contractors. Failing all this steps the items are lined up for future decomposing. (World Health Organization, 2019).

The item needed to be repaired when directed to the maintenance unit through the correspondence book and if it must be forwarded to the public works department workshop the unit in charge will have to send it with a job card. Once the item is repaired it is sent back to the particular unit after being documented in the maintenance unit. If not repairable the items are returned to their respective units pending the condemning process.

Spare parts required for repairs including nuts and bolts are issued by the maintenance stores to workers when requested through the acting supervisor for the respective maintenance unit with the approval of AO.

At present, the maintenance unit is managed by a few technically skilled personnel and a group of nonskilled workers. The situation has worsened with the retirement of most of the qualified and skilled personnel in the recent past. Furthermore, it is observed that there are technically skilled and interested personnel in the SKS (Saukya Karya Sahayaka) a supportive staff category in the hospital. Some of them already have recognized qualifications from vocational training technical institutions

As in most hospitals maintenance and repair of biomedical equipment of the NHSL are handled by engineers and technicians from the Biomedical Engineering division of the Ministry of Health. (De Alwis & Koggalage, 2020)

Problem Statement

The maintenance unit of the National Hospital of Sri Lanka (NHSL) faces significant challenges that hinder its effective operations. Over the past years, the unit has been consistently understaffed, with a shortage of skilled technical staff. According to internal reports, the ideal number of maintenance workers required to efficiently manage the hospital's needs is 60. However, the unit has been operating with only 35 staff members for the past two years.

This understaffing has led to numerous issues, including frequent complaints about the unit's efficiency. Records from the hospital's feedback system show an increasing trend in complaints over the past 18 months, highlighting delays in repairs, prolonged equipment downtimes, and suboptimal performance of medical equipment. These inefficiencies disrupt healthcare service delivery, compromising patient care and safety.

Moreover, the maintenance unit has received feedback from various departments within the hospital, emphasizing the urgent need to enhance operational efficiency. The recurring issues underline the necessity for an overhaul in the maintenance processes and the recruitment of adequately skilled technical personnel to meet the hospital's growing demands.

The objectives of the Study

- To evaluate the efficiency and effectiveness of the current working processes within the NHSL maintenance unit.
- To identify potential areas for improvement in the maintenance unit's operations and service delivery.
- To develop targeted recommendations for enhancing the functions of the NHSL maintenance unit.

Significance of the Study

The significance of this study lies in its potential to contribute to the enhancement of the operational efficiency of the maintenance unit at the National Hospital of Sri Lanka (NHSL), which is crucial for ensuring the provision of satisfactory healthcare services. By analyzing the current working processes of the maintenance unit and identifying the challenges and opportunities for improvement, this study aims to provide practical recommendations that can be implemented to address the identified issues.

The findings of this study are expected to have several important implications. First, the recommendations for improvement can lead to increased efficiency and effectiveness of the maintenance unit, which in turn can result in reduced downtime and improved performance of medical and general equipment (Rommelzwaal, 1997). This can contribute to the overall improvement in the quality of healthcare services provided by NHSL.

Second, the study can provide valuable insights for hospital administrators and policymakers on the importance of investing in the maintenance and repair of medical equipment (Willson, Ison, & Tabakov, 2013). The study can highlight the need for skilled staff, sufficient training opportunities, efficient inventory management, clear outsourcing strategies, and effective communication mechanisms to ensure the smooth functioning of the maintenance unit.

Third, the study can serve as a reference for other healthcare institutions facing similar challenges with their maintenance units. The findings and recommendations of this study can be used as a benchmark for other institutions to improve their maintenance and repair services and enhance their operational efficiency.

Overall, the significance of this study lies in its potential to contribute to the improvement of the maintenance unit at NHSL, which can have a positive impact on the quality of healthcare services provided by the hospital and serve as a reference for other healthcare institutions facing similar challenges.

Literature Review

The importance of maintenance and repair services in healthcare institutions cannot be overstated. Proper maintenance of medical equipment is crucial for ensuring patient safety, improving the quality of care, and prolonging the lifespan of the equipment (Mutia, Kihui, & Maranga, 2012). A well-functioning maintenance unit is essential for the operational efficiency of a healthcare facility, especially in a large teaching hospital like the National Hospital of Sri Lanka (NHSL).

Several studies have highlighted the challenges faced by maintenance units in healthcare institutions. A systematic review conducted revealed factors affecting medical equipment maintenance management and identified issues such as inadequate funding, lack of skilled staff, and insufficient training opportunities as common challenges (Bahreini, Doshmangir, & Imani, 2018). Similarly another study emphasized the importance of having a sufficient stock of spare parts for maintenance and repair activities and the need for efficient inventory management to ensure the timely availability of spare parts (Chen et al., 2019).

The recruitment and retention of skilled technicians is another critical issue faced by maintenance units in healthcare institutions. Study done in Sri Lanka highlighted the importance of having trained biomedical engineers and technicians to manage medical equipment effectively. They emphasized the need for regular training and capacity-building programs to enhance the skills of the maintenance staff (De Alwis & Koggalage, 2020).

The role of outsourcing of maintenance and repair activities has also been discussed in the literature. It emphasized the need for healthcare institutions to have a clear strategy for outsourcing maintenance and repair activities and to establish proper documentation and communication mechanisms to ensure accountability and transparency. The study also highlighted the importance of having a mechanical engineer head the maintenance unit to ensure effective management of the maintenance and repair activities (Herman, 1985).

Furthermore, the importance of having regular dialogues between the maintenance staff and the administration has been emphasized in the literature. A study done in Greece in 2020, highlighted the need for effective communication between the maintenance staff and the administration to address the concerns and issues faced by the maintenance unit (Mourtzis, Siatras & Angelopoulos, 2020).

In conclusion, the literature review highlights the importance of having a well-functioning maintenance unit in healthcare institutions. It also emphasizes the need for skilled staff, sufficient training opportunities, efficient inventory management, clear outsourcing strategies, and effective communication between the maintenance staff and the administration to ensure the operational efficiency of the maintenance unit.

Methodology

The methodology of this study is designed to provide a comprehensive analysis of the functioning of the maintenance unit at the National Hospital of Sri Lanka (NHSL) and make

recommendations for improvements. This study employs a qualitative research approach, which is particularly suitable as it allows for a thorough examination of the working processes of the maintenance unit and the identification of challenges and opportunities for improvement.

Population Size:

The population size for this study includes all employees working within the maintenance unit at NHSL, which totals 35 individuals, 5 workers of public works department, technical officer, ward in charges who have regular interaction with maintenance unit storekeeper and administrative officer.

Sampling Technique:

A purposive sampling technique was employed to select participants who have varied roles and experiences within the maintenance unit. This approach ensures that the study captures a broad spectrum of insights and perspectives, facilitating a comprehensive understanding of the unit's operations.

Sample Size

To ensure a representative sample, the study will include interviews with 8 workers from maintenance units, two workers from the public works department, technical officer, three ward in charges, and storekeeper and administrative officer.

Study Instruments

To gather comprehensive and detailed information, the following study instruments were employed

- Observation Visits
- Key Informant Interviews

Observation Visits

The first component of the methodology involved observation visits to the maintenance units at NHSL. These visits are aimed at gaining a firsthand understanding of the working processes of the unit, the challenges faced by the staff, and the conditions of the equipment and facilities. The researcher conducted several visits to different maintenance units within the hospital premises to observe the day-to-day operations of the unit. During these visits, the researcher interacted with the maintenance staff to gather information about their experiences, challenges, and suggestions for improvement.

Key Informant Interviews

The second component of the methodology involved conducting key informant interviews with sixteen relevant stakeholders. The stakeholders were administrative officers, technical officers, three ward in-charges, eight maintenance unit staff, storekeeper, and two workers of the public works department. All the persons interviewed are having more than five

years of service in the respective positions. The interviews were semi-structured, allowing for flexibility in the line of questioning but ensuring that key topics were covered. The interviews were used to gather detailed information about the working processes of the maintenance unit, the challenges faced by the unit, and the possible solutions to these challenges. The interviews provided an opportunity for the stakeholders to share their experiences, insights, and suggestions for improvement with the researcher.

As an example few quotes expressed by the interviewees are given below : The study identified several key challenges faced by the maintenance unit at the National Hospital of Sri Lanka (NHSL). Delays in repairs were a common issue, with staff noting, "We often have to wait weeks for repairs to be completed, which disrupts our daily operations," and "Even minor repairs take an unreasonable amount of time, affecting our ability to provide timely services." Equipment breakdowns also posed significant problems, as highlighted by statements such as, "Equipment breakdowns are common and cause significant delays in patient care," and "Frequent malfunctions of critical equipment are a major setback, often leading to cancellations of scheduled procedures." Workforce issues were another major concern, with skill gaps in technical tasks and supervising roles being evident: "We simply do not have enough qualified staff to handle the volume of work," and "Supervisory roles are often filled by individuals without adequate technical background, leading to mismanagement." Recruitment delays exacerbated these issues, with remarks like, "The process of hiring new technical staff is slow and bureaucratic, which leaves us understaffed for long periods," and "Delays in recruitment mean that existing staff are overworked, affecting the overall maintenance performance." Communication and recognition challenges further complicated the situation, as noted by staff: "There is a significant communication gap between the management and the maintenance staff, which leads to misunderstandings," and "The hard work of the maintenance staff often goes unrecognized, which affects morale." Training and development deficiencies were also prominent, with quotes such as, "We need more regular and advanced training to keep up with technological advancements," and "Technical training is inadequate; we are not equipped to handle newer, more complex equipment." Additionally, limited space for equipment repair and spare parts storage was a recurring theme: "The space for carrying out repairs is very limited, and it often hinders our efficiency," and "We have very little room to store spare parts, which complicates our work when repairs are needed." Inadequate facilities for staff were also mentioned, with statements like, "The facilities provided to us, such as rest areas and sanitation, are insufficient and not up to standard," and "There are not enough sanitary facilities for the staff, which impacts our overall work environment and productivity." Finally, delays in the supply of spare parts were highlighted as a significant issue: "Getting the necessary spare parts on time is a persistent issue, causing delays in maintenance work," and "Often, we have to wait for weeks for spare parts, which hampers our ability to maintain equipment efficiently."

Thematic Analysis and Coding

The collected data from the key informant interviews were analyzed using NVivo, a qualitative data analysis software. The software facilitated the coding and thematic analysis of the interview data. The thematic analysis involved identifying common themes and patterns that

emerged from the interview data, which helped to understand the key challenges faced by the maintenance unit and the opportunities for improvement.

Overall, the methodology of this study was designed to provide a comprehensive and in-depth understanding of the functioning of the maintenance unit at NHSL, using a qualitative research approach including observation visits and key informant interviews, as well as thematic analysis and coding of the interview data using NVivo.

Results

The results section presents the key findings from the analysis of the data collected in the study. The data is visualized in two ways to provide a comprehensive overview of the challenges and issues faced by the maintenance unit at the National Hospital of Sri Lanka (NHSL). The first visualization is a word cloud that highlights the frequency of words and phrases associated with the problems identified. The second visualization is a thematic analysis table that organizes the findings into themes, codes, and sub-codes, providing a structured and detailed summary of the challenges and areas of improvement. Together, these visualizations offer insights into the various factors contributing to the maintenance unit's performance and the opportunities for improvement.



Figure 1. Word Cloud

The word cloud above visually represents the frequency of words and phrases associated with the challenges and issues faced by the maintenance unit at the National Hospital of Sri Lanka (NHSL). The larger the word or phrase appears in the cloud, the more frequently it was mentioned in the data. This visualization provides a quick way to understand the key themes and areas of concern that emerged from the analysis.

Table 1. Thematic Analysis and Coding Summary

Theme	Node	Sub-Node	Number of Times Mentioned (References)	Percentage Mentioned
Performance Challenges	Inadequate maintenance	Delays in repairs	20	10%

		performance		
		Breakdowns in equipment	10	5%
Workforce Issues	Lack of skilled staff	Skill gaps in technical tasks	30	14%
		Skill gaps in supervising roles	15	7%
	Delay in recruitment	Delays in technical staff recruitment	20	10%
Communication and Recognition Challenges	Lack of regular dialogue	Communication gaps with staff	30	14%
		Overlooking the role of maintenance staff	10	5%
Training and Development	Inadequate training opportunities	Lack of technical training	12	6%
	Insufficient space for maintenance unit	Limited space for equipment repair	12	5%
		Limited space for spare parts storage	4	2%
	Insufficient sanitary facilities	Inadequate facilities for staff	13	6%
	Unavailability of spare parts	Delays in the supply of spare parts	7	3%

Source: Author's presentation

The table above presents a thematic analysis of the challenges faced by an organization in its maintenance operations. The table categorizes the challenges into four main themes: Performance Challenges, Workforce Issues, Communication and Recognition Challenges, and Training and Development.

The first theme, Performance Challenges, highlights issues related to inadequate maintenance performance, with sub-nodes detailing specific problems such as delays in repairs and breakdowns in equipment. These challenges are mentioned a total of 30 times, making up 15% of the total mentions.

The second theme, Workforce Issues, discusses the lack of skilled staff, with sub-nodes emphasizing skill gaps in technical tasks and supervising roles, as well as delays in technical staff recruitment. This theme is mentioned a total of 65 times, accounting for 31% of the total mentions.

The third theme, Communication and Recognition Challenges, points to the lack of regular dialogue and recognition for maintenance staff, with sub-nodes specifying communication

gaps with staff and the overlooking of the role of maintenance staff. This theme is mentioned a total of 40 times, making up 19% of the total mentions.

Finally, the fourth theme, Training and Development, addresses issues related to inadequate training opportunities and insufficient space for the maintenance unit, with sub-nodes outlining the lack of technical training, limited space for equipment repair and spare parts storage, insufficient sanitary facilities, and unavailability of spare parts. This theme is mentioned a total of 48 times, comprising 22% of the total mentioned.

The table provides a comprehensive overview of the challenges faced by the organization in its maintenance operations, categorizing them into specific themes and sub-nodes for a more detailed analysis.

The following problems were identified through the information obtained.

Identified Problems –

- I. Inadequate performance in repairing and maintenance
- II. Inadequate space for the functioning of the maintenance unit
- III. Lack of technically competent staff
- IV. Delay in the recruitment of new technicians
- V. Inadequate training opportunities for the workers
- VI. Noncompliance to some requests due to nonpayment of risk allowance to nontechnical personals
- VII. Nonavailability of skilled supervises for maintenance units
- VIII. Lack of required tools and spare parts
- IX. Inability of maintenance store to supply required spare parts on time
- X. Due recognition is not given to the maintenance unit
- XI. Development of the maintenance unit is hindered due to the practice of outsourcing some repairs
- XII. No proper regular dialogue between maintenance unit workers and the administration
- XIII. Insufficient sanitary and hygienic facilities within the maintenance unit two
- XIV. Absence of a mechanical engineer to head the maintenance unit
- XV. The Public Works Department does not function on weekdays

The fishbone diagram above provides a visual representation of the various factors contributing to the challenges faced by the maintenance unit at the National Hospital of Sri Lanka (NHSL). The diagram organizes potential causes into categories, including Human Resources, Equipment, Training, Processes, and External Factors. Each category is further broken down into specific factors that impact the performance of the maintenance unit. This

visualization helps to identify the root causes of the problems and provides a comprehensive overview of the areas that need improvement.

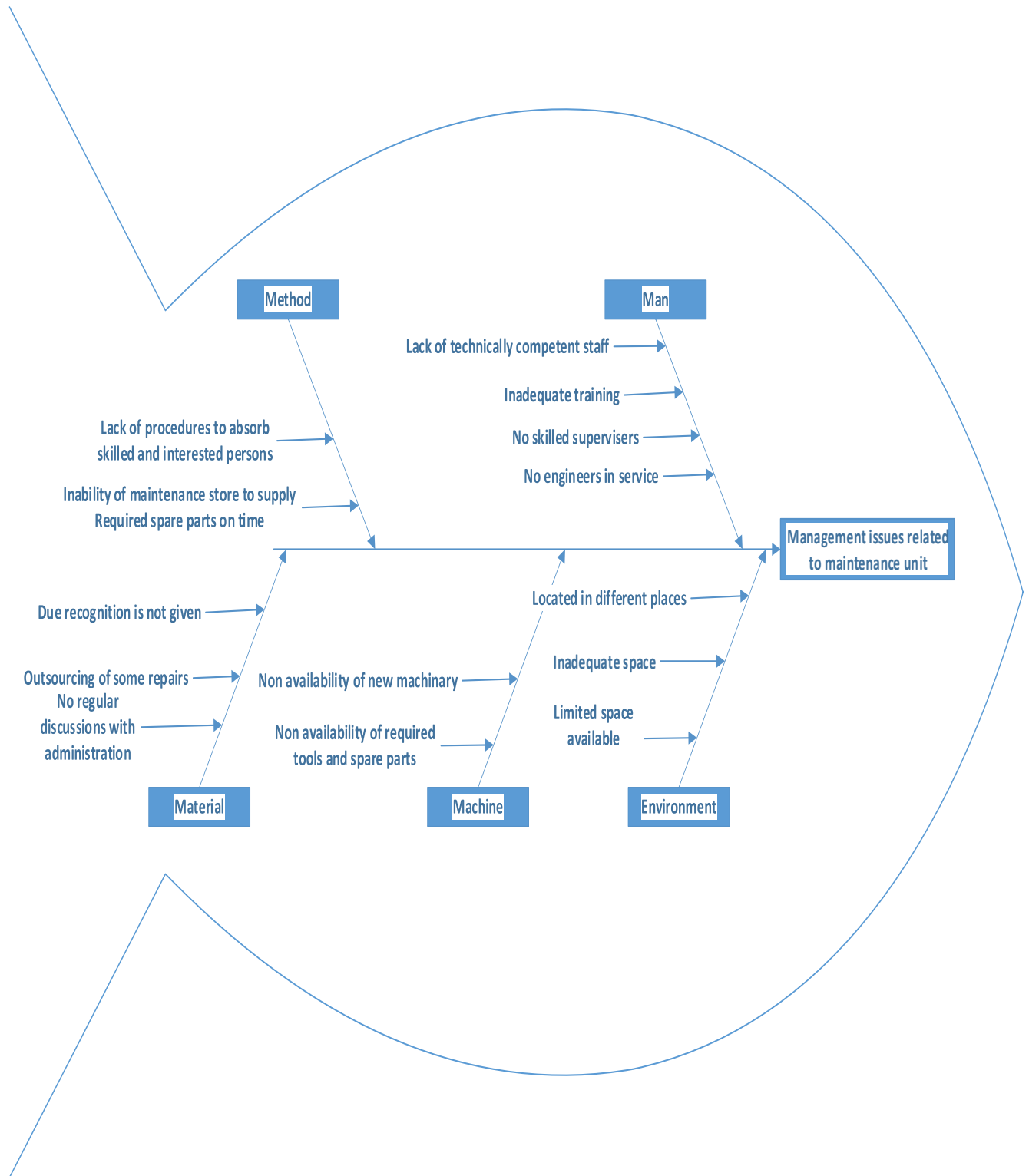


Figure 2. Fishbone Diagram of the Issues faced by the Maintenance Units of the NHSL

Discussion

At present, maintenance units function under severe hardships due to lack of sufficient space. For instance, the workshop area of maintenance unit four and the public worker's department workshop where welding, spray painting and carpentry functions are done are located near the laundry. Whenever loads of soiled linens are taken to the laundry, the staff of the maintenance unit has to interrupt their work.

The motivation of the workforce is less due to various reasons such as not providing adequate training facilities, not being designated as skilled workers, and the non-availability of skilled supervisors. These problems are further aggravated due to the non-recruitment of new skilled technicians and the non-availability of new machinery and tools. It is also observed that there are many vocationally qualified or skilled, interested SKS personnel in the other units but there is no proper strategy to absorb them into the maintenance unit.

Due to the prevailing economic situation of the country the suppliers' default on the supply of spare parts they are agreed on. Because of this unavailability of spares in time, most of the items that would have been repaired and returned for use are sent for condemning wasting resources of the hospital. The present maintenance stores do not maintain sufficient stock of spares needed for repairs. Furthermore, these maintenance unit activities are further complicated due to the development of new technological equipment (Bahreini, Doshmangir & Imani, 2019).

Maintenance units are not specifically developed to handle the repair of particular items through welding, cushion work, woodwork, spray painting, and polishing (Iadanza, Gonnelli, Satta, & Gherardelli, 2019)

Need to arrange training programs to update knowledge and skills of the maintenance staff is highlighted throughout the research. This is more important when considering the advanced technological equipment procured for the NHSL.

Regular dialogs are not happening between the management and the maintenance unit staff. Even in that kind of meeting most of the maintenance unit personnel are reluctant to express their views openly due to fear of the superior members of the staff.

It is noted that the durability of the outsourced repaired items is low at the same time the removed malfunctioning parts from repaired items are not handed back to the institution.

At present NHSL is the only hospital where Public Work Department technicians attend to repair work. Unfortunately, their services are available on Saturdays and Sundays only. But earlier they are functioning all seven days. Moreover, now they only repair iron and steel items only due to lack of space. They can also attend to repairs and maintenance work regarding polishing, cushioning, carpentry.

Limitations

The study primarily relies on qualitative research methods, potentially limiting its generalizability beyond NHSL due to its unique context. Absence of quantitative data collection

methods restricts a comprehensive understanding of maintenance unit's challenges. Implementation barriers like budget constraints and resistance to change are not extensively discussed, potentially hindering feasibility of recommendations. Limited discussion on impact of maintenance inefficiencies on patient outcomes and lack of sustainability discussion further limits depth of conclusions. Addressing these limitations could enhance validity and applicability of study's findings and recommendations.

Conclusion

Providing efficient and effective maintenance and repair services in the institution is vital for the smooth functioning of the National Hospital of Sri Lanka (NHSL). The study has highlighted several key challenges and areas of improvement that need to be addressed to enhance the performance of the maintenance unit at NHSL. These challenges include inadequate performance in repair and maintenance, lack of skilled staff, insufficient space, and delays in recruitment, among others. The findings underscore the importance of taking strategic and targeted actions to overcome these challenges and improve the overall functioning of the maintenance unit at the hospital.

Recommendations

To improve the maintenance facilities at the NHSL, the following recommendations are suggested.

- A central maintenance unit should be established to cover all areas of maintenance and repair of all general items and infrastructural facilities.
- Accommodation for a new spacious central maintenance unit should be provided when more space is available after the opening of the new OPD complex.
- Provision of new machinery and tools to expedite the activities of the maintenance unit.
- Establish a permanent branch of the biomedical engineering division within the hospital to conduct maintenance and repair activities of biomedical equipment.
- Introduction of a proper selection method to identify the vocationally trained or skilled, interested SKS personnel from other units to strengthen the maintenance unit.
- Organize recognized vocational training activities regularly for the staff of the maintenance unit.
- Follow up on the request made to the Ministry of Health for the recruitment of mechanical engineers/ trained technicians for the vacant posts
- Establish a regular mechanism to have a dialogue between maintenance staff and the administration to solve the issue.
- Standards of Sanitary and hygienic facilities for the maintenance unit two should be improved.
- Streamline the documentation of the handing over and returning of repaired outsourced items.
- Maintenance of sufficient stocks of spares, nuts, and bolts by the maintenance store should be a continuous affair.
- Consider reestablishing of Public Works Department workshop functioning on weekdays

References

- Bahreini, R., Doshmangir, L., & Imani, A. (2018). Affecting medical equipment maintenance management: A systematic review. *Journal of Clinical and Diagnostic Research*, 12(4), IC01–IC07. <https://doi.org/10.7860/JCDR/2018/31646.11375>
- Bahreini, R., Doshmangir, L., & Imani, A. (2019). Influential factors on medical equipment maintenance management: In search of a framework. *Journal of Quality in Maintenance Engineering*, 25(1), 128–143. <https://doi.org/10.1108/JQME-11-2017-0082>
- Chen, J., et al. (2019). Maintenance, repair, and operations parts inventory management in the era of industry 4.0. *IFAC-PapersOnLine*, 52(13), 171–176. <https://doi.org/10.1016/j.ifacol.2019.11.171>
- De Alwis, S., & Kogalage, P. (2020). A Project to improve management of biomedical equipment in selected units of District General Hospital, Gampaha, Sri Lanka. *International Journal of Research Foundation of Hospital and Healthcare Administration*, 7(2), 67–74. <https://doi.org/10.5005/jp-journals-10035-1109>
- Herman, A. L. (1985). Equipment maintenance and repair management. *SAE Technical Papers*, 23(73). <https://doi.org/10.4271/850759>
- Iadanza, E., Gonnelli, V., Satta, F., & Gherardelli, M. (2019). Evidence-based medical equipment management: A convenient implementation. *Medical & Biological Engineering & Computing*, 57(10), 2215–2230. <https://doi.org/10.1007/s11517-019-02021-x>
- Malkin, R. A. (2007). Barriers for medical devices for the developing world. *Expert Review of Medical Devices*, 4(6), 759–763. <https://doi.org/10.1586/17434440.4.6.759>
- Ministry of Health Malaysia. (2016). *Medical device guidance document good refurbishment practice of medical device* (GRPMD). Medical Device Authority, 0029(January), 1–16.
- Mourtzis, D., Siatras, V., & Angelopoulos, J. (2020). Real-time remote maintenance support based on Augmented Reality (AR). *Applied Sciences*, 10(5), 1855. <https://doi.org/10.3390/app10051855>
- Mutia, D., Kihui, J., & Maranga, S. (2012). Maintenance management of medical equipment in hospitals. *Industrial Engineering Letters*, 2(3), 9–19. <http://ir.jkuat.ac.ke:8080/bitstream/handle/123456789/706/Maintenance%20Management%20of%20Medical%20Equipment%20in%20Hospitals.pdf?sequence=1&isAllowed=y>
- Rommelzwaal, B. L. (1997). The effective management of medical equipment in developing countries. A series of five papers, *FAKT Project*, (390). http://frankshospitalworkshop.com/organisation/management_documents/The%20Effective%20Management%20of%20Medical%20Equipment%20in%20Developing%20Countries%20-%20FAKT.pdf
- Willson, K., Ison, K., & Tabakov, S. (2013). Medical equipment management. *Biomedical Instrumentation & Technology*, 1–310. <https://doi.org/10.2345/0899-8205-48.4.302>

World Health Organization. (2019). *Decommissioning medical devices*.
<https://apps.who.int/iris/bitstream/handle/10665/330095/9789241517041-eng.pdf>