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Mukunda Chaudhary
Research Scholar, CMJ University, Shillong, Meghalaya, India

Dr. Vinay Pratap Singh
Associate Professor, CMJ University, Shillong, Meghalaya, India

Correspondence
Mukunda Chaudhary
Research Scholar, CMJ University, Shillong, Meghalaya, India

Development and validation of a comprehensive measurement tool for evaluating the performance of medical equipment management systems (Mems) in Indian public Hospitals

Mukunda Chaudhary and Dr. Vinay Pratap Singh

Abstract
Effective management of medical equipment is paramount for delivering quality healthcare services in public hospitals. The study aims to develop and validate a robust measurement tool specifically tailored for assessing the performance of Medical Equipment Management Systems (MEMS) in the context of Indian public healthcare facilities. This research responds to the unique challenges faced by public hospitals in India, such as resource constraints, high patient loads, and diverse healthcare needs. The research methodology involves a multi-step approach. First, a systematic review of existing MEMS performance measurement frameworks and tools will be conducted to identify gaps and opportunities for customization to the Indian healthcare environment. Subsequently, a comprehensive measurement tool will be developed, incorporating key performance indicators (KPIs) relevant to the Indian scenario. The tool will encompass aspects such as equipment availability, maintenance, calibration, inventory management, and user satisfaction. To validate the measurement tool, data will be collected from a representative sample of public hospitals across different regions of India. Through surveys, interviews, and on-site observations, the tool's effectiveness in assessing MEMS performance will be evaluated. Statistical analysis will be used to establish the tool's reliability and validity. The findings from this study are expected to offer insights into the strengths and weaknesses of MEMS in Indian public hospitals. It will provide hospital administrators, policymakers, and healthcare professionals with a valuable instrument to identify areas for improvement and optimize the utilization of medical equipment. Ultimately, this research can contribute to enhancing the quality and efficiency of healthcare services in public hospitals in India, with the potential for adaptation in similar healthcare settings globally.

Keywords: Comprehensive, measurement, medical equipment

Introduction

Many scientists around the world have conducted in-depth research and discussions on medical device management in different countries. American and colleagues conducted qualitative research on the factors that influence the care and management of medical devices in military hospitals. His research was summarized in an article published in the journal Military Medicine. Using the framework analysis tool, he conducted a survey specifically targeting health care and management professionals at a hospital serving in the military. Semi organized interviews are used to analyze the data and descriptive statistics are applied to prioritize the frequency of occurrence of the various criteria that influence the maintenance management of medical devices. Based on the results of the experiments, a significant portion of the total can be attributed to device management training. Of course, they took into account how convincing the results might be to others, but the sample size was quite small, so it was unavoidable. Ms. Ulickey has studied a significant number of complex cases requiring integrated facilities management systems. In the past, networking and technical advancement of digital control systems have enabled the integration of a wide variety of control strategies [1].

This was achieved using a number of different control schemes. These strategies apply not only to the management of building systems, but also to the management of health facilities. The development of new scientific knowledge provides a stronger mathematical foundation for the logical application of a wide range of medical technologies, paving the way for more efficient use of available resources.

In the future, people should focus on learning how to properly understand this data and improving the system's ability to make informed planning decisions [2].

With advances in science and technology, hospitals in the United States are investing more and more time and resources in the management and maintenance of their medical equipment. According to Qiang, the availability of advanced medical technologies is one of the most important aspects of the technological infrastructure of hospitals today. Therefore, it is the responsibility of the hospital to create an effective management model, manage medical equipment to ensure it is kept in excellent working order, and ensure the safety of hospital patients and visitors. Topics related to the maintenance and management of hospital medical devices and the development and characteristics of the maintenance management model and the current situation in Germany and abroad have been summarized with different methodologies, including literature searches, surveys, questionnaires and data analysis. some data. These methods were used to collect and analyze the data. However, it did not present any evidence to support its claim that the use of modern Internet technology to build intelligent systems in medical device management is highly practical. He claimed that this was the case, but did not present any evidence to support this claim. It also did not provide any data to support its claims that the benefit had been demonstrated in specific field studies [3].

This research has laid the groundwork for an in-depth analysis of the integrated medical device management system that will be based on cloud computing and the Internet of Things in the future. Most of the research is based on the following parts, which serve as a basis: The first section of this article discusses the technologies and methods used in the development of the system. Some of these include cloud computing and task scheduling, IoT intelligent control system, particle swarm algorithm, and chicken swarm optimization algorithm. Other methods include cloud computing and task scheduling. Therefore, this article discusses the network architecture, software structure, development environment, database, and other components to create a complete resource management system platform. These and many other topics are covered in more detail later in this article. In summary, this research model simulates the system's impact on real-world applications, as well as a variety of potential barriers, from the perspective of acquiring and distributing medical devices, as well as the maintenance, operation, and use of medical devices [4].

It was found that between 25% and 35% of the equipment failed prematurely due to insufficient maintenance costs, which was the other important situation. In many cases, it would be more economical to improve maintenance to extend the life of existing equipment and reduce downtime for repair or replacement than to purchase new equipment. According to the conclusions of an analysis of the situation of health technologies in developing countries, the current situation is far from adequate. This can be attributed to misuse of resources and equipment, coupled with the lack of a structured needs assessment process Due to a lack of data on the many devices used in the public health system, purchases are generally ad hoc and unscientific. This leads to the import of several computers. The World has provided a striking example of the diversity of equipment in underdeveloped countries, such as the fact that multiple models of the same machine are used in hospitals. An example of this is the fact that there are different types of X-ray equipment. In addition, reports indicate that the vast majority of equipment was not installed and commissioned on site, even after it was brought there [5].

In general, no progress can be made until adequate steps are taken to design and implement national health technology policies that are acceptable at the national level. Without this policy it will be impossible to move forward. In particular, these policies should influence a number of factors, including equipment levels appropriate for the country, equipment standardization, equipment purchasing, equipment installation and commissioning, management staff structure, and the maintenance and establishment of complementary information systems. As a direct consequence, the objective of this thesis is to investigate the potential application of reengineering to the process of development and management of medical devices. The work is divided into three parts, the first of which is a preliminary analysis focused primarily on identifying key issues and identifying challenges in the Ethiopian scenario. The second section is dedicated to the redesign process of the medical device management system (reengineering) and the third section is dedicated to the design implementation process through the use of information systems (MIS) and the development of office software.

Objectives

1. "To assess the effectiveness of the MEMS program in participating public hospitals against selected key performance indicators (KPIs)".
2. To examine the interrelationships between key performance indicators (KPIs) for input, process, output, and output of MEMS systems.

Research Methodology

The purpose of the research methodology section of the document is to provide a description of the methods and procedures used to achieve the objectives that have been defined for the study in question. "The objective of this research was to create and apply key performance indicators to assess the proper functioning of MEMS in public hospitals, with the ultimate goal of improving the quality of care provided to patients. Consequently, the research was developed in two well differentiated phases: the development phase and the application phase".

To design a measurement tool, the main source of information was interviewing the experts who participated in the study to obtain their views and opinions. This served as an important source of information for primary data acquisition. Personal observation and questionnaire completion were the primary means by which the researchers collected data during the implementation phase of the study, which formed the second part of the research project and is discussed in more detail below. A survey was conducted to collect the opinion of people who work in the medical field and are responsible for the "operation and management of various medical devices. Secondary data for the previous year was collected by examining various MEMS-related records and documents stored in hospitals. This process was carried out last year" [6].

Development of Research Tools
Most of the study was conducted in one of two periods. To design the research tool, in the first part of the study, key performance indicators (KPIs) and a corresponding multidimensional scaling (MDS) were developed. Furthermore, a group of industry experts proposed and reviewed that a conceptual framework should be designed and validated for the comprehensive evaluation of MEMS in public hospitals in India. Subsequently, they were used "in the second phase of the study in the form of a structured questionnaire to collect the required information on MEMS from the public hospitals that were part of the ongoing investigation".

Suggest expert opinion search tools
It consisted of developing 30 KPI elements, 110 MDS elements and a conceptual framework for a comprehensive evaluation of MEMS in public hospitals. The brochure (Appendix I) was presented to all the experts for an informative session on the topic and on the research methodology. However, a consent form (Annex III) was also included for their voluntary participation".

Development of the key figures of the presentation
The KPI development process was carried out in three phases:

KPI definition
A comprehensive review of the MEMS literature was conducted and suggested for the development of key performance indicators (KPIs) for the industry. The review focused on policies, "guidelines, and practices for inventory management and record keeping; Preventive Maintenance; Corrective maintenance; availability of spare parts and consumables; security practices; medical device health; reporting of adverse events; and usage behavior. The main inspiration for the development of KPIs came from the rules set by the World Health Organization, the Department of Health and Welfare, the Government of India and many other developed countries for the management of medical devices in public hospitals. towns. These rules have been implemented in public hospitals around the world" [7].

Related KPIs
"After a thorough study of the scientific literature, a rationale for each KPI was outlined. The models also mention the type of KPI (qualitative/quantitative), the method of data collection and analysis, the source of data collection. The observation period was maintained for a period of one year".

Propose and register KPIs
It was important to keep track of all parts of the quality management system to achieve a balanced state within the measurement system. As can be seen in Table 1, 11 key performance indicators (KPIs) were proposed from the perspective of the service consumer, 11 were proposed for internal management, five were proposed for continuous improvement and three were proposed from the point of view of financial view. Essentially, the researchers agreed on actionable and achievable key performance indicators (KPIs) by selecting them based on readily available data and literature. The Key Performance Indicators (KPIs) have been developed using SMART (Specific, Measurable, Achievable, Relevant and Timely) criteria to ensure they are relevant and timely in the context of public hospitals in India. These criteria require KPIs to be Specific, Measurable, Achievable, Relevant and Timely [8].

Development of a minimal "data set"
The following steps were followed to prepare MDS elements suitable for analysis:

- Identification of MDS elements/parameters related to specific MEMS practices for research purposes,
- Identification of specific KPIs for different aspects of MEMS,
- Fusion of KPIs with the MDS,
- Identification and mapping of the MDS elements used to operationalize the variables in the MEMS conceptual framework,
- Refine these elements under each KPI with the help of expert advice; Y
- Refine these elements further by performing an analysis of the elements of each dataset covered by a single KPI.

After collecting feedback from industry professionals, a set of 110 MDS items was submitted against a set of thirty recommended Key Performance Indicators (KPIs), which were then revised. Based on the information in Table 4, it was decided that the KPIs numbered 1-9, 12-14, 17, and 19-22 should each have 4 different data points, as did the KPIs numbered 12-14, indicator 15, 16, 18, 24, 26 and 28 to 30, two criteria were proposed for each of the 4 groups. KPI 10 should have six data items, KPI 11 should have eight parts, and KPI 23 should have 10 items. It has been suggested that KPIs 25 and 27 each require only one data item to be replaced [9].
A full set of these factors and MDSs were used in the process of developing the questionnaire that will be used "for data collection in the second part of the study, the application phase. The" process the researchers followed to create the questionnaire is outlined in the flowchart shown the process the researchers followed to create the questionnaire is depicted in the flowchart to the right.

Building a complete framework for MEMS
To create and classify the components of the proposed Key Performance Indicators (KPIs), extensive research was carried out on the relevant literature. To achieve this, an in-depth study of both official MEMS/MEMP documents from developed countries and quality management methods was carried out. Throughout the process of developing this document, the views and expectations of healthcare executives, users (physicians, dentists, nurses, and senior technical experts), and academia have been taken into account (Joshi, 2009). Several key performance indicators (KPIs) were created, so these KPIs were grouped and divided into 4 main components or areas. These were the input/process, output/result, and result components. As a direct result of this, the structure shown in Figure 9 was created. This framework was made up of 4 parts: "input (8 KPIs), process (8 KPIs), output (6 KPIs), and result (8 KPIs). In assessing the efficiency and effectiveness of the framework, and thus the overall evaluation of MEMS" each of the Key Performance Indicators (KPIs) included in each of the 4 areas served a unique purpose [10].
All the input indicators represent the resources needed to operate the system, while the process indicators refer to the

routines performed by users and administrators in the daily management and handling of medical devices. - Every day. Input flags are divided into two distinct groups: resources necessary for system operation and unnecessary resources. The result indicators, which are the result of these activities and efforts, reflect the expected or desired results when the medical equipment was installed in the hospital, and the result indicators, which are the result of these activities and efforts, reflect how much the organization does well in relation to strategic management as a whole.

Before the developed and designed KPIs, MDS, and overall framework were given the green light for approval, expert opinions were solicited on the specificity, measurability, feasibility, relevance, and usefulness of each of these elements. This was done according to the "five characteristics of specificity, measurability, accessibility, relevance and timeliness (SMART criteria). They were also asked to provide feedback on the relevance and completeness of the elements, sections and frames as a whole, as well as on the overall structure of the document". The experts were asked to express their opinion on the evaluation matrix (Annex V), which was based on a 5-point Likert-type scale (1 = strongly disagree, 2 = disagree, 3 = disagree, 4 = agree agree and 5 = strongly agree). = strongly disagree, 2 = disagree to improve the statistical reliability and validity of the total score for each domain, it was necessary to perform further statistical checks on the total score for each domain. "To make the proposed measurement instruments and the conceptual framework even more reliable and valid, the" following tests were performed: a) spurious validity; b) validity of the content; c) analysis of the articles; d) verification of internal consistency and reliability; ee) [11].

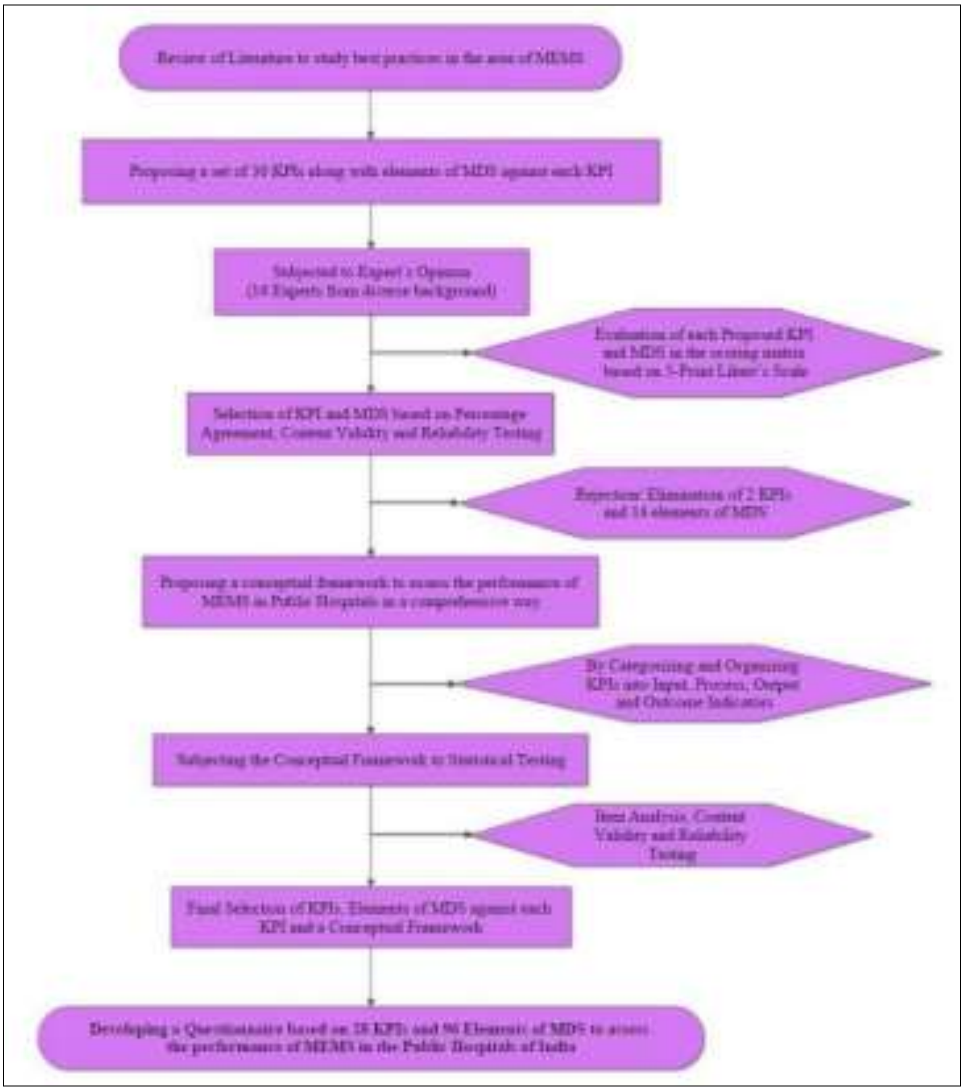

Fig 1: Flowchart - Survey Questionnaire

"As part of the item analysis, items (key performance indicators, or KPIs) were evaluated along with domains for item difficulty (mean values), item distribution (standard deviation), and item discrimination. This was done to determine whether or not the items were compatible with each other to accurately measure the overall concept. To test the internal consistency and reliability of the framework as a whole, Cronbach's and Guttman's half-reliability coefficients for the total score were also checked" [12].

Results and Discussion

The data collected and analyzed in this chapter were further detailed in the previous chapter, according to the objectives and purposes of the "study. The first part of the study involved the development and validation of measurement tools for research, such as the definition of Key

Performance Indicators (KPI), the Multidimensional Scale (MDS) and a conceptual framework, all included in the first three main objectives of I study". This part of the study was divided into two parts. The researchers then used these tools in 4 different public hospitals to assess the overall effectiveness of the MEMS system. This was the continuation of the second part of the research project. In the second phase of the project, two main objectives and two secondary objectives were added. As a result, the research project had a total of 7 objectives, each of which was examined and analyzed individually and detailed in various "sections of this chapter" [13].

Before distribution, the validity and reliability of the meter were examined through the prism of various statistical methods. The conclusions were positive. A significance level of 0.05 was used to assess the study objectives and the results were calculated taking this into account. A simple analysis of variance was performed to allow comparison of the efficiency of 4 hospitals. Pearson's correlation coefficient was useful to analyze the data collected during the process of analyzing the relationship between the different elements of the conceptual framework. The use of linear regression analysis was necessary to accomplish the task of determining the results of the secondary endpoints. In this particular scenario, the CPU value was expected against the KPI totals and health values.

Go Alone

Under the first objective, Key Performance Indicators (KPIs) were prepared for public hospitals in the Indian setting using MEMS best practices for public hospitals in the country. As mentioned in the previous chapter (Table 1), a set of thirty key performance indicators (KPIs) were provided and their reliability was assessed, as explained in more detail in the next section. Ultimately, the proposed KPIs, also known as KPIs, were only listed and selected after they were determined to meet the agreement criteria. [14].

Table 1: List of proposed KPIs

KPI #	Proposed KPI	Under the perspective
1.	MEMS Policies and Guidelines	Internal administration
2.	Responsibility	Internal administration
3.	Patient-Centered Approach	Service user
4.	Human Resources	Internal administration
5.	Biomedical engineering services	Service user
6.	Infrastructures and structures	Internal administration
7.	MEMS funding/grant allocation	Financially
8	Risk management	Continuous improvement
9.	Registration and documentation	Continuous improvement
10.	Preventive Maintenance	Continuous improvement
11	Security practices	Service user
12	Precision and quality control	Continuous improvement
13	Formation and development	Continuous improvement
14	Corrective maintenance	Internal administration
15.	Cost-benefit analysis	Financially
16	POE and instructions for use	Internal administration
17	usage model	Service user
18	Reliability of medical devices	Internal administration
19	Patient safety	Service user
20	Employee safety	Service user
21	Service cost report	Financially
22	User satisfaction	Service user
23	Duly updated inventory	Internal administration
24	Duty cycle (percent)	service user
25	Availability index	Internal administration
26	Percentage of PPM compliance	Internal administration
27	TAT medical equipment repair	Service user
28	Percentage of Repairs Completed	Service user
29	Percentage of medical devices in operation	Service user
30	Percentage of medical devices in maintenance	Internal administration

The overall percentage of agreement of the experts is shown in the figure and can be seen below. The percentage of overall agreement is presented in Table 2, which also includes a summary of the results. The qualities with the highest percentage of agreement were Achievable, 93% (Relevant), 87.1% (Punctual) and Specific, while the rest of the characteristics presented the lowest percentage of agreement. Consequently, each of the characteristics showed an agreement percentage greater than 70%, which was considered the minimum necessary to demonstrate the agreement of the experts. The subjective review of the reviewers allowed to demonstrate the justification of the recommended tool, both aesthetically and in terms of content. This was achieved by evaluating the content of the tool. In addition, the experts were asked to share their views on the key insights and areas in which the recommended KPIs were ranked.

Table 2: Percentage of agreement between experts

Attribute	Tall in disagreement	In disagreement	I cannot say it	To accept	Tall To accept	percentage okay
Specific	0.0	2.1	6.9	42.9	48.1	**91%**
Measurable	0.0	2.5	12.3	46.9	38.3	**85.2%**
Realizable	0.0	1.7	12.7	46.0	39.6	**85.6%**
Important	0.0	1.5	5.6	41.7	51.3	93.0%
On time	0.0	1.9	11.0	52.3	34.8	87.1%

The calculations and reliability check of Guttman's half and Cronbach's alpha of each key performance indicator (KPI) were performed using the statistical program SPSS version 23. The reliability of the entire instrument, which is the sum of all indicators key performance indicators (KPIs), have been tested individually in addition to the reliability of each individual KPI. To perform the Guttman split-half reliability calculation, the data set was split in half to produce two separate halves. The first section included three aspects: 1 (specific), 2 (measurable), and 3 (indicating overall quality) (attainable). The second part, like the first, consisted of three characteristics, namely qualities 3, 4 and 5 (all important). Table 1 summarizes the results of the reliability and hypothesis tests for each KPI using a Kolmogorov-Smirnov (KPI) test on one sample. The importance of each individual characteristic (SMART) of each key performance indicator (KPI) was evaluated against the hypothesis. The theory turned out to be correct.

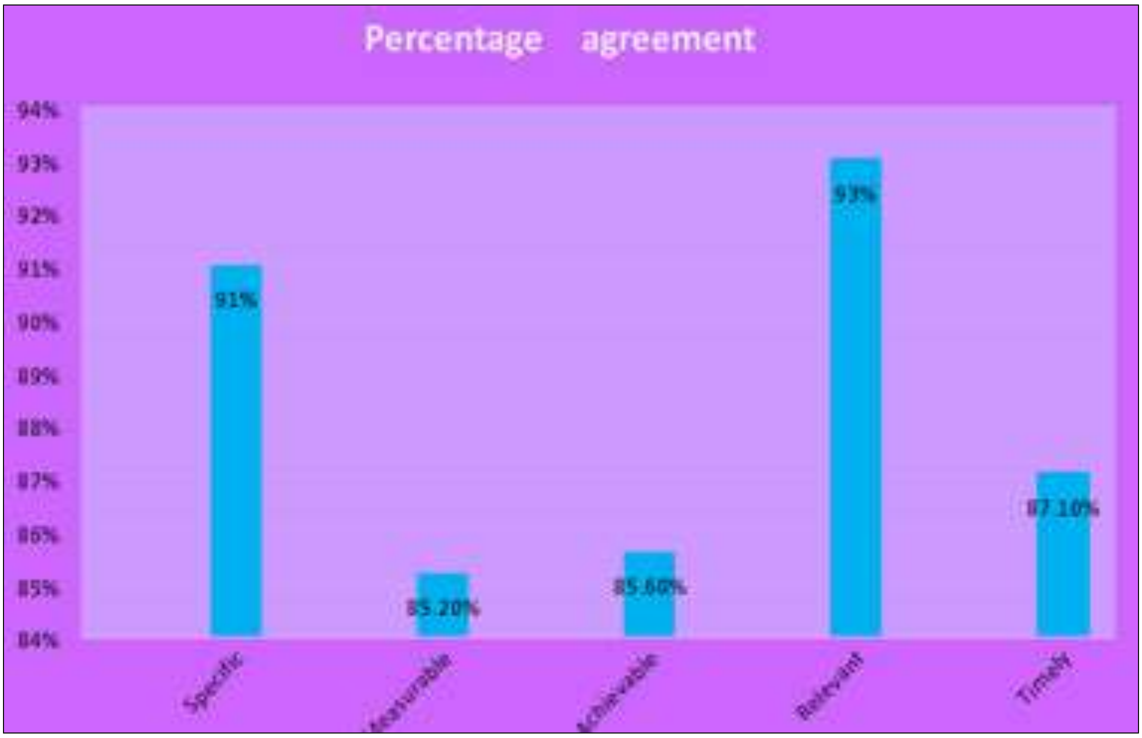

Fig 2: Overall percentage of agreement among the experts

Cronbach's alpha scores ranged from 0.77 to 0.98, while Guttman's split reliability of all agreed KPIs ranged from 0.78 to 0.95 on the Guttman scale. All discussed and decided KPIs had the same values of 0.87 and 0.85 respectively, and therefore the overall scale for all KPIs was considered reasonable. After completing a single Kolmogorov-Smirnov sample for hypothesis testing purposes, the "p" value was found to be less than 0.05, indicating that the null hypothesis was invalid, untested (Fig. 2). This showed that it is statistically significant to maintain the five distinct properties, namely specificity, measurability, feasibility, relevance, and timeliness, as important components of all selected KPIs. Specificity refers to the degree to which an indicator can be measured. Measurability refers to the degree of feasibility of an indicator (KPI) [15].

Statistics were used to examine the overall percent agreement, reliability, and importance of each feature. The results showed that there was nothing wrong with any of the factors. In the end, a set of 28 key performance indicators (KPIs) were selected from a set of 30 recommended KPIs based on their ability to meet the statistical test criteria. This selection was made from the group of suggested KPIs. According to Table 1, two key performance indicators, KPI no. 15 (cost-benefit analysis) and KPI no. 17 (usage model) were removed from the final collection of KPIs because they did not meet minimum standards for reliability or hypothesis testing. These two KPIs have been removed from the final collection of KPIs.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of attribute 1 is normal with mean 4 and standard deviation 0.500.	One-Sample Kolmogorov-Smirnov Test	.000[1]	Reject the null hypothesis.
2	The distribution of attribute 2 is normal with mean 4 and standard deviation 0.750.	One-Sample Kolmogorov-Smirnov Test	.018[1]	Reject the null hypothesis.
3	The distribution of attribute 3 is normal with mean 4 and standard deviation 0.500.	One-Sample Kolmogorov-Smirnov Test	.000[1]	Reject the null hypothesis.
4	The distribution of attribute 4 is normal with mean 4 and standard deviation 0.516.	One-Sample Kolmogorov-Smirnov Test	.000[1]	Reject the null hypothesis.
5	The distribution of attribute 5 is normal with mean 4 and standard deviation 0.574.	One-Sample Kolmogorov-Smirnov Test	.000[1]	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

[1] Lilliefors Corrected

Fig 3: "Statistical significance of the SMART criteria"

Conclusion

It was found that the medical device quality management strategy based on key performance indicators (KPI) could be used to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire to hire medical device management plan in public hospitals should be approved in an integrated and comprehensive manner, provided that it is based on a conceptual framework with 4 domains of input, process, output and result. On this point, too, all parties agreed. More importantly, the feedback they provided on the Likert scale for the data items validated the concept that the MDS for MEMS serves as a decision support system for healthcare managers. This gives healthcare executives the opportunity to assess and make the right decisions to improve management effectiveness.

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Author's Contribution

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