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RESEARCH ARTICLE

DESIGNING AND VALIDATION OF AN INTEGRATED PERFORMANCE MEASUREMENT FRAMEWORK FOR MEDICAL EQUIPMENT MANAGEMENT SYSTEM IN THE PUBLIC HOSPITAL

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ABSTRACT

Background and Aim: This manuscript is aimed to develop a theoretical framework for performance management and measurement of Medical Equipment Management System (MEMS) based on key performance indicators (KPIs) which fits well in public hospital context of India and other developing countries.
Material and Methods: The paper is based on literature analysis followed by statistical analysis. Study design consisted of selection of a set of KPIs and their organization into a simple logic model consisting of four domains of input, process, output and outcome. These domains and the integrated framework were subjected to the reliability and validity testing by statistical methods.
Results: 28 numbers of valid KPIs were selected and organized into domains and further into an integrated framework for comprehensive measurement of the performance of MEMS for the public hospital in an effective and efficient manner.
Conclusions: Establishment and validation of the framework for MEMS was an attempt for holistic management of the medical devices from the perspectives of the primary healthcare stakeholders and the patients. The framework will also be useful to find out the strengths and weaknesses of MEMS at an individual organizational level. Moreover, based upon the measuring tool of KPIs, it also helps at an early stage to make the appropriate changes and quality improvements in the system.

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INTRODUCTION

Performance measurement is an act of comparing the actual performance (measurement) with that of the expected or desired performance. Performance measurement is an important part of Total Quality Management (TQM) of any organization. It is the responsibility of the healthcare managers and administrators for assessing health-care services in such a way that the activities and efforts are directed towards the achievement of strategic goals of the organization (Kueng, 2000). It is an essential methodology and technique used to improve the quality and ensure the accountability of health-care service providers. There has been a rapid increase in the efforts for the development of performance measurement systems for evaluating government or not-for-profit organizations, where health-care processes and outcomes at various levels are leading to evaluation and comparison between similar aspects of care at each level (Persaud and Nestman, 2006).

Medical Equipment Management System (MEMS): The Medical Equipment Management System consists of all the activities related to medical equipment including inventory and record keeping, maintenance strategies, equipment failure &repair machinery, safety & quality control, training of the users and maintaining all the data and indicators to prepare the management reports and decisions for the future planning & improvements (Chien, Huang and Chong, 2010).

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Framework: The term 'model' or a 'framework' demonstrates a comprehensive concept of performance measurement as well as the significance of individual components by explaining the diversity of relations existing among them. The idea behind the development of "integrated framework", i.e., developing a system for performance measurement is more goal oriented (Wagner, 2008).

Framework for Quality Management System in the Hospital; Basic elements: It is a basic responsibility of a hospital manager or the hospital administrator to build a comprehensive framework of any management system enabling the diagnostic analysis of needs of all the stakeholders as well as maintaining the quality of the hospital services. According to Nur and colleagues, (Nur, Dawal & Dahari, 2014) while designing a framework, it is important to keep eight essential elements in mind consisting of; a) Resources; b) Activities; c) Patients; d) Processes; e) Leadership; f) Policy and strategy;g) Society; and h) Performance results. While designing such a framework, it will evolve into a quality driven model while fulfilling the strategic goals of the organization as well.

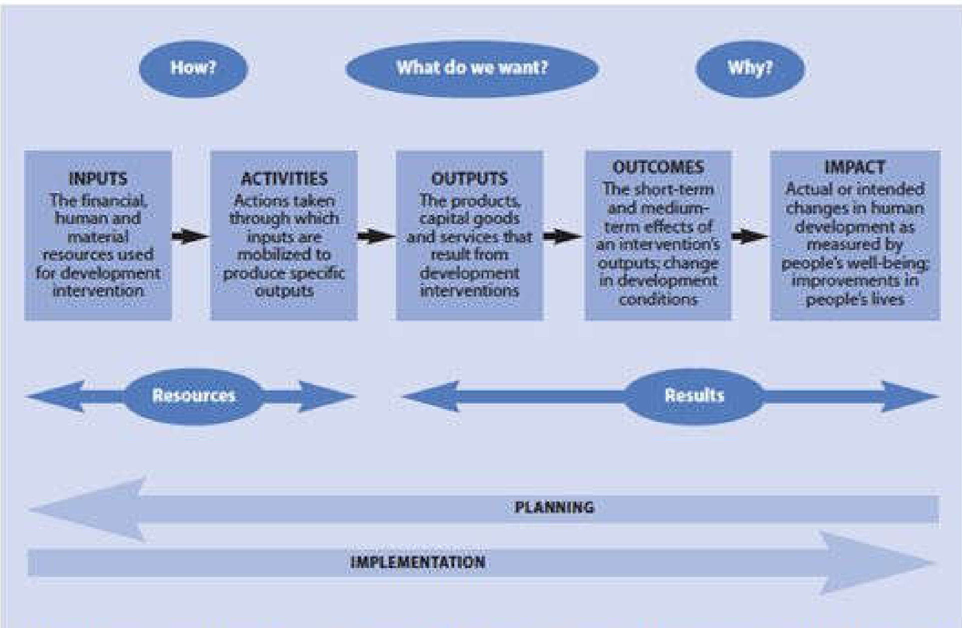
Fig. 1 represents a reference model for the Performance Measurement System which is based on industry best practices. Such type of comprehensive framework based upon the logic model consisting of the four domains of input, process, output and outcome are often used in public or not-for-profit organizations, where the mission and vision are not aimed at achieving a financial benefit. In such situations, where return on investment or the profits are not the expected results, it may be difficult to monitor progress toward outcomes. A program logic model incorporated with the KPIs provides a solid framework and foundations at which output and outcome measures of performance can be monitored effectively and efficiently. Henceforth, it is important to carefully specify the desired results in such organizations and there is a need to put sincere efforts to control and monitor the activities over time (Logic model workbook, Washington, DC, 2011).

Therefore, a conceptual framework provides a solid foundation for the monitoring and evaluation of a program. This acts as a guide (Marcelino-Jesus *et al.,* 2016):

1. To understand the underlying concepts of the entire program.
2. Helps the managers to find the ways to implement the monitoring and evaluation activities.
3. Can help in deciding and analyzing short, medium and long-term goals.
4. It defines the relationship existing between input, process, output and outcome indicators of the program/management system.
5. It distinguishes the internal activities and the influence of external factors over the program.
6. It demonstrates in a logical way that how the resources and activities will lead to the desired outcomes.

Literature review

Medical technology not only acts as an enabler to make a correct diagnosis and a timely clinical management of the patient but it also helps the clinician and other healthcare professionals to treat patients in a cost-effective and efficient manner. Thus the technology facilitates to integrate the systems management in a way that contributes to an overall improvement in the level of health indicators. At the same time the hospital and clinical administrators are faced with the challenges of expectation for return on investment and they are held accountable for the financial constraints existing in the organization (David and Jahnke, 2004). All these factors demand an accountability framework to be operated in the health care organizations. Moreover, it becomes the duty of hospital medical engineering personnel also to ensure the safety of the patient, as well as that of the staff. In order to achieve such safety and efficiency, a comprehensive, well-designed MEMS program in the hospital is mandatory.



Source: UNDP Handbook on Planning, Monitoring and Evaluation for Development Results (2009, p55)

Fig. 1. Simple Logic Model

Moreover, it is the duty of biomedical engineering professionals to review the management strategies periodically so that they can fulfil the expectations of patients and practitioners as well. It is highly critical to anticipate the impact of ineffective MEMS on a group of patients while making diagnoses and clinical decision making for surgical interventions orroutine therapies (Wang *et al.,* 2006). The literature study highlights that the status of MEMS in the government/public hospital of India is not adequate. A study carried out by Lathwal and Banerjee (Lathwal and Banerjee, 2001)in the public hospitals of district Gurgaon of Haryana revealed that only 39.3% of the medical equipment were utilized adequately, rest were either non-functional (35.5%) and one fourth were just reserved without putting them in current use. Approx. 28% equipment were kept for condemnation and 7.3% were kept for repair. The reasons for less availability, non-functioning and under-utilization of equipment were found to be improper and poor system of maintenance and repair, and tendency to keep some of them in reserve for their future use, in case of breakdown of the existing ones.

Another study conducted by Pardeshi (Pardeshi, 2005) in the Indian public healthcare facilities by reviewing the reports of Comptroller and Auditor General of India (CAG) revealed various problems in all stages of life cycle of medical equipment. This study also supported the findings of Lathwal and Banerjee about the sub-optimal availability and utilization of equipment in the government health centers and hospitals of India. The literature witnesses the poor status of MEMS in the developing countries. A study conducted by Perry & Malkin (Perry and Malkin, 2011) revealed that in the data collected from 16 developing countries, 38.3% of medical equipment were in non-working conditions. Their study also concluded that the main factors causing non-functional status were mainly lack of trained personnel, inadequate infrastructure and the poor management system. A study done in Sri Lanka (Dasanayaka and Sardana, 2011) was also related to the ineffective MEMS and poor upkeep of healthcare equipment in 12 major Sri Lankan public sector hospitals. The findings of the study concluded that non-existence of national healthcare technology management policy was the main factor responsible for poor management of healthcare equipment. The authors recommended major changes in restructuring the systems and accountabilities in public health system of the developing countries. An integrated web-based framework for MEMS was also used by Chien, Huang and Chong in Taiwan (Chien, Huang & Chong, 2010) for the in-house clinical engineering department. They recommended to use the framework for maintenance of the medical equipment as it could manage the equipment more efficiently, safely and reduce the cost also. The literature review also supports the fact that the concept of an integrated framework to measure the performance of MEMS in the public hospital has not been applied both in India and abroad.

Statement of the problem

There is a dearth of a comprehensive framework available to measure the performance of the management system for the costly medical equipment in the public hospitals of India. Secondly, to avoid the irrelevant elements creeping into the performance measurement system, it is important that the framework must be made statistically reliable and validated too (Wagner, 2008). Henceforth, the present study has been aimed to put efforts in designing and validating a conceptual framework based on KPIs to measure the performance of MEMS in the public hospital in an Indian perspective, with the following objectives:

1. To propose an integrated framework for MEMS based on KPIs under the four domains of Input, Process, Output and Outcome.
2. To find the validity and reliability of the proposed framework.

MATERIALS AND METHODS

To achieve the said objectives, best practices related to MEMS were studied in depth by undergoing systematic literature survey and a set of 30 Key Performance Indicators were selected and validated by adopting the 'SMART' criteria (Chaudhary *et al.,* 2016). To construct the framework, the selected KPIs were categorized and organized into the four domains of input, process, output and outcome. The framework thus created was subjected to the expert opinion to be approved under five characteristics of specificity, measurability, achievability, relevance and timely (SMART criteria). 18 experts from the diverse backgrounds were invited for the purpose. They were also asked to give their remarks on the completeness of the items, domains and the framework as a whole. The experts expressed their views on 5-point Likert's scale (1= strongly disagree, 2= disagree, 3= can't say, 4= agree and 5= strongly agree) for each item corresponding to each domain of the framework. To make the framework reliable and valid statistically, the aggregate score of each domain was subjected to: a) face validity, b) content validity, c) item analysis, d) internal consistency and reliability testing; and e) split-half reliability testing. SPSS version 23 was used for the purpose of validation and reliability testing of the framework. For the item analysis, the items (KPIs) and domains were checked for item difficulty (mean values), item spread (standard deviation) and item discrimination to examine whether the items fit with others to measure the overall concept. The Craunbach's alpha and Split- half reliability was also checked for the comprehensive score to examine the internal consistency and reliability of the framework as a whole unit.

Criteria for deciding the Reliability and Validity of the Framework

1. **Content validity:** For content validity of each item (for each KPI and each domain of the framework), at least 80% of the experts must agree (must give his/her opinion for 4 i.e., 'agree' or 5 i.e., 'strongly agree' on the measurement scale). 80% of agreement of the experts will be computed as the CVI of 0.80 for that item (Barbe, 2015).
2. **Item discrimination:** this index helps to differentiate importance/ability of every item of the framework and is determined by correlating the score on each item with overall test score. An item to total score correlation of 0.2 is said to be the cutoff point and the items less than 0.2 should be discarded (Ajmera, Gupta and Singh, 2014).

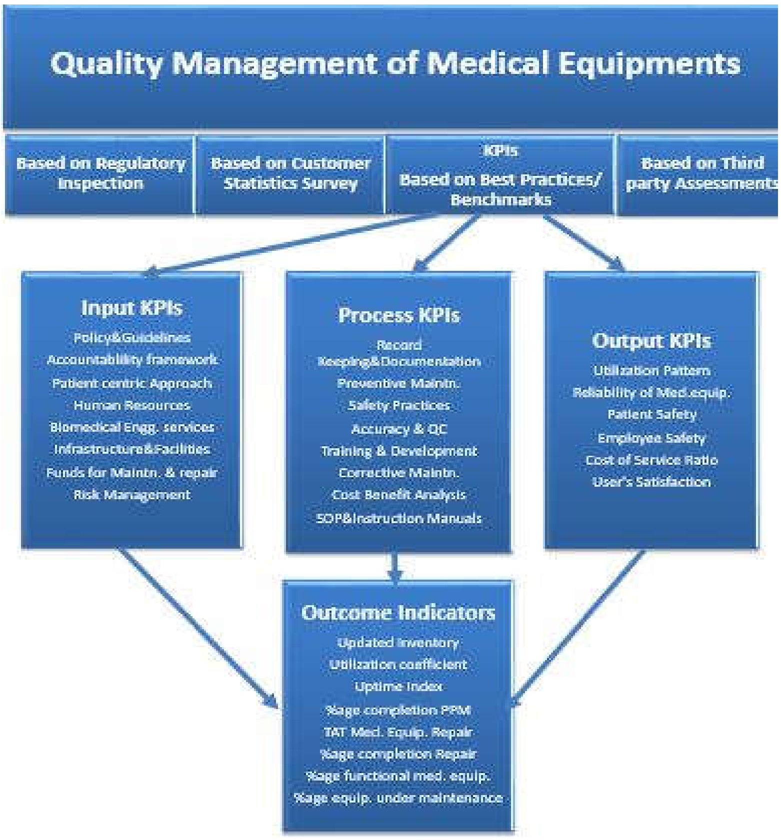


Fig. 2. A Proposed Framework for MEMS in the Public Hosptial Context

Table 1. Summary of Results

Item no.	Item/ KPI	Agreement (%)	Content Validity Index (CVI)	Mean	SD	Corrected Item-Total Correlation	Cronbach' Alpha if Item Deleted	Domain
1.	Policy and Guidelines for MEMS	100	1.0	25.69	2.774	.547	.928	I-1
2.	Accountability framework	100	1.0	25.88	3.096	.369	.930	I-2
3.	Patient-centric approach	94.4	.94	25.94	3.214	.507	.928	I-3
4.	Human resources	100	1.0	26.13	3.222	.573	.927	I-4
5.	Biomedical engineering services	100	1.0	26.25	2.206	.809	.926	I-5
6.	Infrastructure and facilities	94.4	.94	25.44	3.076	.479	.929	I-6
7.	Funds/grants allocation for MEMS	94.4	.94	25.88	3.519	.474	.929	I-7
8.	Risk management	88.9	.89	24.56	4.049	.620	.927	I-8
9.	Record keeping and documentation	100	1.0	28.31	2.056	.413	.929	P-1
10.	Preventive maintenance	88.9	.89	25.88	3.096	.527	.928	P-2
11.	Safety practices	94.4	.94	25.94	3.214	.560	.928	P-3
12.	Accuracy and Quality control	88.9	.89	26.13	3.222	.686	.926	P-4
13.	Training and development	94.4	.94	26.25	2.206	.581	.928	P-5
14.	Corrective maintenance	94.4	.94	25.44	3.076	.424	.932	P-6
15.	Cost-benefit analysis	72.2	.72	20.19	4.136	.194	.662	P-7
16.	SOP & instruction manuals	94.4	.94	24.56	4.049	.579	.927	P-8
17.	Utilization pattern	77.7	.78	21.50	2.280	.164	.558	O-1
18.	Reliability of medical equipment	94.4	.94	26.00	2.898	.643	.926	O-2
19.	Patient safety	94.4	.94	25.75	1.949	.610	.927	O-3
20.	Employee safety	94.4	.94	27.44	2.394	.627	.927	O-4
21.	Cost of service ratio	94.4	.94	26.25	3.235	.292	.931	O-5
22.	User's satisfaction	88.9	.89	25.75	1.949	.575	.927	O-6
23.	Proper updated inventory	94.4	.94	27.63	2.306	.496	.929	OC-1
24.	Utilization coefficient (percentage)	88.9	.89	25.50	5.060	.618	.927	OC-2
25.	Uptime index	94.4	.94	26.31	4.771	.553	.928	OC-3
26.	Percentage completion of PPM	88.9	.89	24.81	3.970	.637	.926	OC-4
27.	TAT of medical equipment repair	94.4	.94	24.81	3.351	.797	.924	OC-5
28.	Percentage of completed repairs	94.4	.94	23.56	6.572	.598	.929	OC-6
29.	%age functional equipment	94.4	.94	25.25	3.109	.748	.925	OC-7
30.	%age medical equipment under maintenance program	100	1.0	27.63	2.306	.807	.925	OC-8
Aggregate score	16.8	93.3	0.93	25.55	3.212	.58	.91	

I-Input KPI, P- Process KPI, O-output KPI, OC- Outcome- KPI
SOP- Standard Operating Procedures

3. **Internal Consistency and Split-half Reliability:** These indices are important to maintain the accuracy of the measuring instrument and to ensure consistent results over repetition and duplication of the test/measurement. The criteria for both the coefficients were kept for the value above 0.75(Yang *et al.,* 2016)

Table 2. Reliability Statistics; Four Domains

Domain	Cronbach's Alpha	Split-half Coefficient
Input	.873	.899
Process	.861	.846
Output	.869	.923
Outcome	.889	.950
Comprehensive (Framework)	**.930**	**.815**

RESULTS

A conceptual/theoretical framework consisting of 30 KPIs was proposed. These were organized under the four domains of input (8 KPIs), process (8 KPIs), output (6 KPIs) and outcome (8 KPIs) as shown in fig. 2. Individual KPI listed in table 1under the four domains play its own role to determine the efficiency and effectiveness of the MEMS. All input indicators represent the resources which are essential to run the system, process indicators relate to the practices carried out by the users and managers while handling the medical devices in routine, output indicators give the results of the activities and efforts put in the direction and the outcome indicators represent the expected/desired outcomes for which the medical devices were installed in the hospital and in turn reflect the strategic management of the organization as a whole.

1) **Face validity:** 95 % of the experts commented that the items selected for the four domains were specific, measurable, achievable, relevant and could be determined with in a time frame of one year (as decided in the protocol). They also responded that the layout and the contents and appearance of the framework was appropriate and practical to implement in the public hospitals and thus ensuring a good face validity of the framework.
2) **Content Validity:** 93.3 % of the experts showed agreement for the content of the items and an overall CVI (content validity index) of 0.93 showed a satisfactory content validity of the framework. However, two items no. 15 and 17 showed the CVI below 0.8.
3) **Item Analysis:**
a) **Item Difficulty:** it was expressed in the form of item statistic by taking the mean value of every item. An aggregate mean value of all the items was 25.5.
b) **Item Spread:** Standard deviation of each item determined the spread of items in the framework. The average value of all the items was 3.2.
c) **Item Discrimination:** two items no. 15 (cost benefit analysis) and 17 (utilization pattern) showed the values below 0.2 and hence were excluded from the framework.
4) **Reliability Analysis:** Craunbach's alpha coefficient if item deleted were above 0.9 (except the items no. 15 and 17) and hence ensured a good internal consistency of the framework. A comprehensive score of the reliability for the four domains was 0.93.
5) **Split-half Reliability:** Split-half coefficient for the comprehensive framework was .82 was suggestive of good reliability of the framework. (Table 2)

By analyzing the results of content validity and item analysis of the entire items/domains of the framework, out of 30 proposed items, item no. 15 and 17 were finally excluded from the final list as these didn't fulfill the statistical criteria of the CVI and reliability coefficients.

DISCUSSION

The study focused on the establishing a framework for performance assessment of MEMS. A refined framework for assessing the performance of MEMS measures and arriving at metrics needs was established. These metrics were established keeping in mind the objectives of the organization and important aspects of quality patient services to be imparted. Using this framework, every healthcare institution can evaluate itself; determine its performance level, set benchmarks and aim for continuous quality improvement. Studies have shown that the implementation of such frameworks for the performance measurement can facilitate to identify the core areas which need changes in a particular direction which seem to be the most appropriate one (Dilanthi *et al.,* 2002). Thus the framework can help to explore many new factors which can lead to organizational successes. Measuring the performance of MEMS will help to justify investment and maximize asset utilization in the public hospital. A common framework can be an important instrument for decision-making in relation to procuring medical equipment and its maintenance arrangements. Therefore, it can form a good basis for quick overview of the current problematic areas and needed actions. Applying the common framework methodology makes it possible to examine the current activities and potential areas of improvements.

Conclusions and Recommendations

The present study utilizes the evidence-based medicine and expert consensus opinion to establish linkages between processes of care and their outcomes. The health-care activities and organizational routines are modified using the concept of key performance indicators developed by understanding the best practices of the MEMS. The selected KPIs were organized into domains and further into a framework. 30 items were proposed for the framework of MEMS and were organized into four domains of a simple logic model. The decision criteria for the statistical significance of reliability and validation testing was fulfilled by 28 KPIs viz. 8 KPIs were selected for input domain, 7 KPIs for the process, 5 KPIs for the output and 8 KPIs were finalized for the outcome domain of the framework. By analyzing the feedback of each domain keeping the quality improvement aspect of performance measurement as the main focus, in turn, can improve the health outcomes.

The Scope and Future Implications of the Study: The present study will provide an evidence-based and methodical decision making framework by using various key performance indicators in the management of medical equipment in the healthcare organizations especially the public sector.

This framework possesses good content and face validities, excellent reliability and therefore it should provide an important and useful tool for measuring the performance of MEMS in public hospitals perspective. However, in order to add more strength to the robustness of the framework for future research, it is recommended that construct validity by calculating the convergent and discriminant validity of each domain of the framework must be carried out by using other statistical tests like confirmatory factor analysis. It is also recommended that the various domains and proposed KPIs of the framework must be tested for inter-relationship by carrying out systematic studies. It is the need of the hour to put efforts in the direction that how the utilization pattern of the medical equipment can be improved by assimilating various key factors and adopting effective maintenance strategies.

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