Providing a Framework for Improving the Maintenance Management Process in Health Sites - Case Study: Selected Hospitals of Mazandaran Province

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Abstract

Background and Objectives: The Department of Medical Services has a long-standing goal to improve the quality and operation of clinical management by efficient use of materials. The present undertaking structures and aspects of the continuing critical evaluation of current support operations in the Medical service department (MSD) -constraint semi-governmental emergency centers, including the re-appropriation and eventual management of temporary workers and services. The key test is to see how maintenance activities can be managed even more easily and conducted more cleverly. In this paper, a mechanism was developed to answer these questions: only with correcting the processes and at the lowest cost possible, how can we improve the maintenance operations?

Methods: For this purpose, current procedures and circumstances in 2 general hospitals in Mazandaran province in Iran are studied and data were gathered via questionnaire, interviews, and observation from 66 people including managers, supervisors, and employees. 56 questions were posed about 5 factors affecting maintenance management and their reliability was confirmed through the Cronbach's alpha method. To analyze these questions, a wide range of statistical techniques such as Spearman's rank correlation coefficient, Chi-squared test, Cramer's V and Factor Analysis were used by SPSS software. Then for a more accurate survey, tools like Critical Success Factors, Key Performance Indicator, the theory of constraints & the Current Reality Tree are utilized.

Findings: Results have shown that effective factors in the improvement of maintenance management can be divided into 4 important principles called continuous learning, clarity in policies and procedures, encouraging innovation and balancing the number of maintenance employees with the work volume.

Conclusions: These four principles can form a useful framework with the lowest cost to improve the current maintenance management procedure in the hospitals which are under review in this paper's case study.

Keywords: Maintenance management, Hospital, Process improvement, Healthcare system

Background and Objectives

Performance and unwavering quality assurance have been examined by a variety of researchers as their results have been extended to a broad range of ventures, including item design, development, finance, retail, and change. Through planning, quality assurance, and unwavering quality management, two unmistakable concepts are frequently utilized by partners to refine the intended outcomes/objectives to be accomplished. Data, process structure, observation, and control are generally recognized[1]. Unwavering continuity is a practical principle that helps reduce the number of breakdowns and is reliably calculated at a rate of disappointment. It is defined as the possibility of carrying out all the capabilities with consistent observations over a fixed time in the states of usage[2].

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The term has a strong correlation with building service jobs because routine machinery and device repair has to ensure that it can function effectively and securely. Condra suggested that unwavering consistency should be measured based on two measures: the rate of dissatisfaction and the expense of disappointment[3].

To order to explain the simple understanding of maintenance jobs, it is necessary to identify what assistance is. European Standard EN (2001) describes maintenance as a "combination of any qualified organization and administrative activity during the lifespan of an item intended to preserve or restore it to a state under which it can exercise the control needed."[4]. In any event, Waeyenbergh and Pintelon found maintenance to be a crucial instrument for growing severity rather than just overhead costs that need to be managed[5].

Help strategies can be classified into three broad classifications: proactive maintenance, prescient maintenance, and remedial maintenance. At a period when the benefit is being reassessed at a pre-ordained date, this is considered proactive assistance. Prescient assistance is said to have arisen when it is modified by the interpretation of the benefit. It is sometimes referred to as conditional assistance. Restorative support is attempted when the gear is separated or cannot work as planned. Preventive and pre-scant assistance is constructive, whereas remedial assistance is sensitive. The notion of a line of maintenance refers to the partnership between the extent of service and the agency responsible for maintenance.

Support systems/strategies fluctuate from team to community, since there is no single-size-fits-all configuration. The preference will be based on a master assessment of hazards relative to possible functional disappointments and the associated impact on procedures[6]. Different responsibilities on the part of the leaders and the board are essential for the effective operation of the support network, as maintenance tasks are regularly treated as overheads for the partnership[7].

Maintaining executives is one of the significant capacities that help to decide on the implementation of the activities of the association. It usually consists of three stages of market action: central, strategic and operational[8]. At the critical point, the activities aim to identify and connect business needs with support needs. At the strategic level, the drills aim to determine the best outcomes of support abilities, resources, and supplies. At the organizational stage, the operations are focused on ensuring that the functions of the organization are carried out within the period allotted to reasonably skilled persons and with suitable resources.

The management program is a calculated process that involves the coordination, recording, updating and evaluation of the different processes containing the tasks/exercises in an organized fashion to promote the execution of the assistance properly. Upgrading the management structure is not a simple undertaking that requires the support and collaboration of senior management as well as all related capacities.

The health care program is constantly viewed as a critical resource to the general population because it makes it easier to avoid and cure diseases even as it protects the social and physical well-being. The development of a

health care network is an expensive endeavor for many governments across the world because the provision of adequate hospital facilities typically adds greatly to the government's overall budget plan. According to the World Health Organization[9], the overall expense of medical treatment exceeded $ 5 trillion and accounted for about 10% of the GDP of the developed nations in 2008.

In 2012, overall social security expenditure in the United Kingdom contributed GBP 144.5 billion, or 9.8% of GDP, while figures for other developing countries included: USA 15% of GDP ($3 trillion), France 11.6%, Canada 11.2%, Germany 11.3% and Japan 9.6%[10]. Not all health-related technologies are used to distribute medications to patients. Hadfield reports that more than 75% of any dollar expended on medical treatment is lost on non-persistent evaluation activities[11].

As far as building maintenance is concerned, the medical services sector has unique working characteristics that allow it to seek to follow the traditional execution of the exec. In any case, Green et al. observed that detailed metrics do not accurately calculate the types in the clinic owing, for the most part, the vast volume of information to be processed in the on-going premises[10] and the effort/time to analyze the information gathered before any movements could be made[12]. It was proposed that more influential attention would be granted at the time of choosing[13].

The points of the present inquiry are twofold:

• Improve awareness of the role of executives in the social security sector in Iran and its effect on the provision of medical care through emergency clinics and authorities.

• To add to the improvement of upkeep the board structure for the medical services industry in Iran.

There are many articles in the maintenance field and based on health care facilities in hospitals, those articles can be divided into 6 groups: 1- Maintenance management 2- Maintenance Management Strategies 3- Maintenance Function 4- Maintenance Costs 5- Maintenance Management in the Health Care System in Advanced Countries and 6- Maintenance of the health care system in Iran, which is described in the rest of the paper.

Maintenance Management

Hospitals may offer comprehensive resources, and their extensive network of operations needed to maintain facilities is one of the key challenges in maintaining facilities[14]. Facility managers have an important role in predicting the facilities' status based on their experience, beliefs, perceptions, and expectations[15].

Among existing approaches, these three are very popular to achieve optimal maintenance levels: Failure Mode, Effect and Criticality Analysis, Root Cause Failure Analysis and Reliability-centered maintenance[16].

Maintenance can happen either be immediate or delayed[17].

After reviewing this topic's literature in his book "Maintenance Management Framework", Márquez points out seven challenges, including the absence of maintenance management model, a wide range of variety of maintenance problems and lack of knowledge and information about the machine/process[2].

Maintenance Management Strategies

The maintenance strategy is defined as "the combination of all technical and executive measures, including monitoring, to keep an item in or return it to a position where it can perform the intended function"[18].
Maintenance strategies are subdivided into unplanned and planned[19]. The main factors that determine maintenance strategies are budgets and crises (as well as complexity) resulting from failure[20].

Maintenance Function

Performance measurement is a tool that enables an organization to develop a systematic process for values assessment, proper managing an organization and delivering results to customers and other stakeholders[21].
Menge et al. compared different models of performance measurement in facility management. These models include the Balanced Score Card (BSC), Business Excellence Model (BEM), Key Performance Indicators (KPIs), and Capability Maturity Model (CMM)[22].
Enshassi et al. identified the absence of formal monitoring and repair preparation as a significant concern in the evaluation of hospital results[23].

Maintenance Costs

Ikediashi et al. found 74 hospitals to study their familiarity with outsourcing repair activities. Outsourcing relies on international knowledge, and thus, existing abilities and experience would be overlooked[24].
Alzaben et al. also developed a Current Reality Tree (CRT) to recognize core problems impacting

hospitals and postpone maintenance. The planned expenditure restrictions, shortage of replacement parts, lack of professional expertise, undefined obligations, accumulation of complaints, incompetence by the contractor and lack of motivation to complete research were major factors in postponing repair activities at the hospital[25].

Maintenance Management in the Health Care System in Advanced Countries

According to the World Health Organization, the health care system costs across the world have exceeded 7 trillion USD and it consumes about 10% of GDP in 2015[26]. Nesje analyzed the allocation of facilities administration expenses at St. Olav University Hospital in Norway and observed that the costs of care and renovation of machinery, electricity, and sanitation compensate for nearly one-third of the hospital's total operating costs[27].

Maintenance Management for the Healthcare System in Iran

Iran is a country with an area of 1, 648, 195 km^2 and is the producer of 4.95% of crude oil, 17.6% of natural gas, 7.7% of electricity, and 1.28% of the world's steel[12]. But with a population of nearly 80 million people in 2017, which represents a major market for the healthcare industry, due to economic and political problems, it has failed to provide a suitable capacity of opportunities to improve it. When Jadidi et al. were implementing the maintenance system in a hospital in Arak, they realized that no one had been trained for 21.7% of the medical devices during the installation and setup phase, and 83.8% of the devices

had not been working with fixed operators[28].

The World Health Organization released a report stating that cardiovascular disease accounts for 46% of all deaths[29]. Next in line is also death by accidents (14%) and cancer (13%), which due to the need for complex hospital services, puts a high pressure on the government to invest more in the healthcare industry. According to the data presented by the Iranian Statistics Center in 2017, there are 1.48 beds per 1,000 people in Iran. This amount is compared with other countries in the same year (2016) in **Error! Reference source not found.**[30].
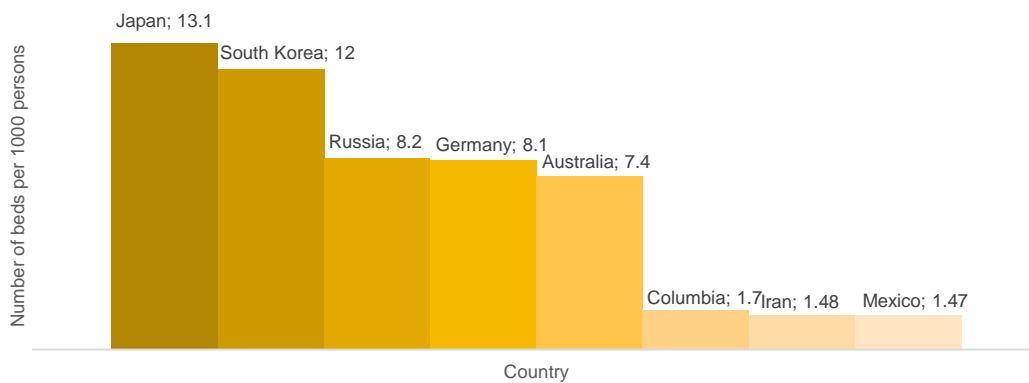

Figure 1- Number of active beds per 1000 persons[30]

It also includes the bulk of repairable medical supplies are imported. In recent years, imports of these items have grown and this requires more attention from maintenance managers due to the financial problems of the country[30].

Articles' Classification

To have a better understanding of proper maintenance management, a literature review had to be done. In that process, as it is shown in table[10] (1), from the beginning of the year 1998 to the spring of 2019, 7 articles about maintenance management of medical equipment have been published. For example, as it is represented in figure[12] (2) and table (2), Garg and Deshmukh divided the maintenance management into 6 key areas[31].

Table 1: articles related to maintenance management in different areas.

Author	Year	factors	Methods	Research Description
Mueller & Bezella[32]	1985	Health thresholds, device malfunction types, working and emergency procedures	Mathematical modeling	In the light of proven unwavering consistency approaches, Mueller and Bezella have established a program-based approach to the survey/assessment of safety limits, process frustration procedures, functioning and crisis strategies for power plants, especially in the nuclear power industry.
Rees[33]	1998	strategic development, business planning	Interviews	Reviews the degree to which facility managers are in a role to control the strategic growth, corporate strategy and policy-making of their company.
Condra[3]	2001	reliability	Analytical	Proposed that unwavering consistency should be measured based on two measures: the rate of satisfaction and the cost of disappointment.
Shohet and Lavy[34]	2004	healthcare FM	Analytical	This paper explores the state of the art in the key fields of healthcare FM and identifies the core principles for the creation of a paradigm for the management of healthcare facilities.
Garg and Deshmukh[31]	2006	categorizes the published literature	Literature survey	The article systematically categorizes and then methodically analyzes and discusses the existing literature.
Ventovuori et al.[35]	2007	literature review	Literature survey	This paper is based on a literature review and qualitative research. Qualitative data have been gathered from academic papers published in FM- related journals (i.e. Facilities, Journal of Facilities Management, and the Nordic Journal of Surveying and Real Estate Research – Special Series) and in conjunction with academic conferences (i.e. European Research Symposium in Facilities Management and the CIB W70 Symposium) between 1996–2005.
Lavy et al[36].	2010	KPIs	qualitative approach	A qualitative methodology focused on literature has been introduced. This method focuses on comprehensive literature reviews of current academic articles, appraisal findings, surveys and presentations to classify KPIs. The KPIs shall be grouped into relevant categories based on their intent and material.
Yousefli[37]	2017	maintenance management functions	Literature survey	The paper categorizes the literature and adopts a summary structure focused on maintaining control roles of hospital buildings. It discusses the effect of these tasks on the success of maintenance operations in hospitals.
Galán et al.[38]	2018	a general review about the maintenance process	Literature survey	This article is focused on a general review of the maintenance process and its management models through time and analyses in a particular way its impact in the hospital sector.
Peykani et al[39].	2018	productivity	mathematical modeling	The explanation for this paper is to propose a novel approach for quantifying the effectiveness of therapeutic improvements after some time in the sight of qualitative variables alongside fuzzy details.
Saeedian et al[40].	2018	non-orchestration factors such as the most	mathematical modeling	Or, on the other side, there is a perplexing system of lots of experts communicating with each other, so the operator-based leisure approach is an appropriate method for showing

Author	Year	factors	Methods	Research Description
		frequencies are related to the lack of recovery beds		OR managers, interactions, characterizing defeats of entities and analyzing the effects of the process implementation. Recognizing The non-organizational causes, the majority of cases are classified as the shortage of treatment rooms, disaster medical procedure, consultant pause, absence of patient transferor, prolongation of other surgery, sedation and pediatric medical procedure; and the lower the incidence for surgical adjustments in patient condition, lack of monitoring.
Rezapour[41]	2018	ability to predict VAS outcomes to reduce failures of surgeries	Literature survey, Case study	The purpose of this inquiry was to provide a system with the capacity to predict the effects of the VAS to reduce the disappointments of medical procedures. The number of diabetic patients was 73 and 117 individuals had hypertension. Their hemoglobin level was 4.9 to 16. Their systolic circulatory pressure (BP) and diastolic BP were in the ranges[95-230] and[60-120] respectively. Using the fluffy management system, the following findings were explored: I As systolic BP increases, the progression of AVF improves (ii) In young patients, the incidence of AVF dissatisfaction is higher than that of more developed patients; (iii) Rising patients from "Youthful" to "Moderately Aged" induces a transition from "AVF disappointment" to "late maturation" status; (iv) In mature patients, high systolic BP with low diastolic BP, changes from "late" AVF to "late maturation"
Jandali and Sweis[42]	2019	maintenance management performance	Case study	The purpose of this paper is to identify and analyze components that affect the public execution of managers and private medical clinics in Amman-Jordan. Open clinics were seen to upgrade more clinical procedures than private medical clinics. The understanding of the support staff in the two departments as to the factors influencing the management of the operation of the board has shifted.
Wanigarathna et al[43].	2019	digital capabilities	Information modeling	This paper aims to explore how specialized technologies relevant to building data display (BIM) will organize a broad variety of data to enhance the functionality of the produced executive tool (BAM) during the time of usage of medical clinic structures.
Gu et al[44].	2019	effectiveness and leadership performance- maintenance theories	conceptual model	Build up a theoretical model to explain the position of CBHKS in the emergency clinic of the board in the light of the selection of adequacy and authority execution of speculations. To test the analysis speculations in the applicable model, the research information collected from 214 experts was gathered and the information inquiry was carried out using fractional least squares (PLS)-based specific proof.
Li et al[45].	2020	maintenance efficiency	conceptual benchmarking framework	A far-reaching simulated benchmarking method, taking into account five cost-effectiveness metrics, patient satisfaction, resilience and asset competence, board adequacy, and operation and efficiency help, is introduced to promote benchmarking of output assessments in medical clinics.

Author	Year	factors	Methods	Research Description
Karimi et al[46].	2020	maintenance	multi-attribute decision-making (MADM)	This paper is acquainted with the strongest–but disgusting–a technique to fathom multi-property dynamics (MADM) problems in a fluffy society. There is no compelling reason in the current approach to doing all the possible pairwise correlations. At the end of the day, only the comparison connections should be done.
Page et al[47].	2020	operational status of a component of a medical device	mathematical modeling, time series analysis	Frameworks and techniques for tracking the management of most of the regulated clinical gadgets include the collection of gushing-time clinical gadget details from the majority of clinical gadgets observed. The gushing period structure of clinical gadget details is broken down to assess the operating status of one of the clinical gadget of the plurality of the clinical gadgets being evaluated. The clinical gadget service approach is derived from the operational status of the clinical gadget unit.
Iadanza and Luschi[48]	2020	Computer-Aided Facilities Management Systems	real-world experiences	The multifaceted complexity of current medical clinics as far as secondary, creative and authoritative requirements are concerned has been growing exponentially over the years. Emergency hospitals may adhere to countless requirements to meet their legal and administrative responsibilities. PC Aided Facilities Management Systems have become essential tools for the management of such an elevated level of multifaceted complexity with an all-encompassing approach. Even now, licensed experiences are emerging, portraying some of the personalized instruments used every day in simple clinics in Tuscany.
This paper		Creation of the Healthcare Maintenance Management System, Implementation and evaluation of current maintenance techniques, Strategic assessment	Literature surveys, Data analysis, mathematical analysis, multivariate analysis, conceptual framework	Improve awareness of the role of the Board of Directors in the human services sector in Iran and its effect on the provision of social insurance programs through medical clinics and pro centers.
To contribute to the development of the organization of executives for the pharmaceutical services industry in Iran.
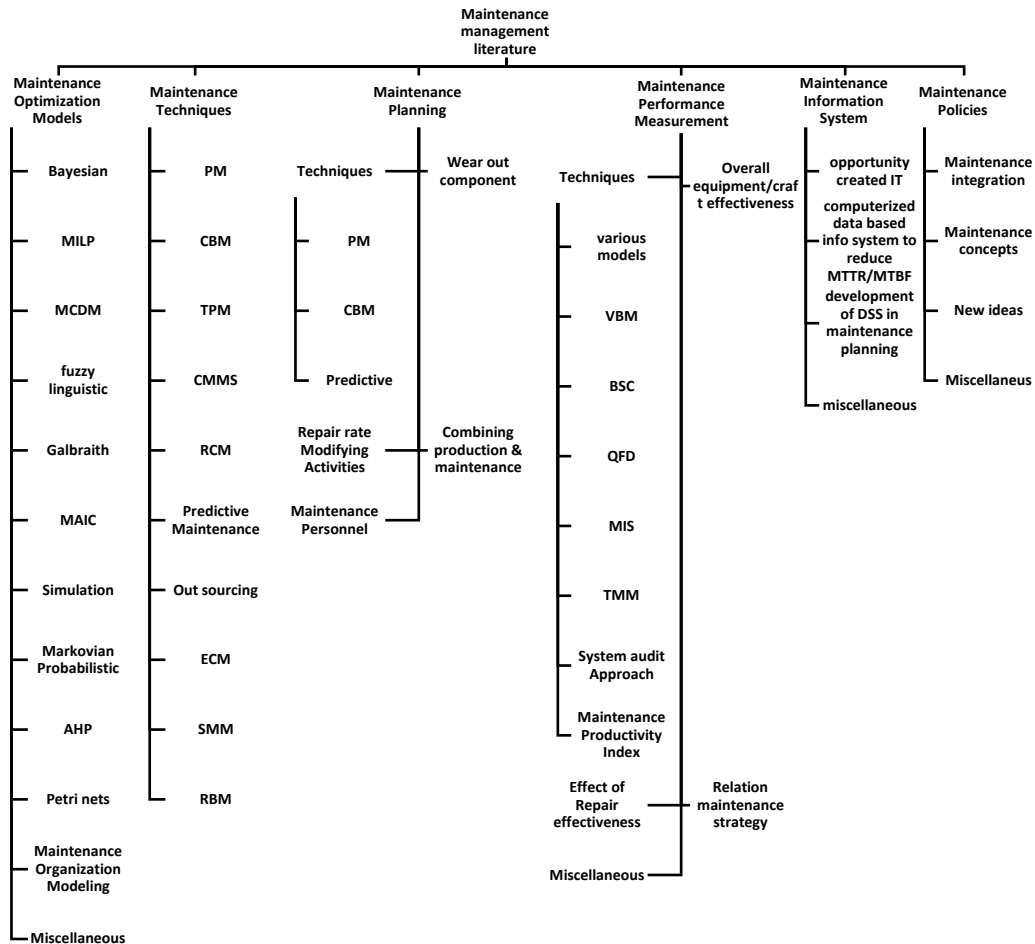
Abbreviations for figure

Abbreviation	Title	Abbreviation	Title
MILP	Mixed Integer Linear Programming	RBM	Risk-Based Maintenance
MCDM	Multiple-Criteria Decision Making	VBM	Vibration-Based Maintenance
MAIC	Materially per Apparecchiature de Impiariti Chemiei	BSC	Balanced Score Card
AHP	Analytic Hierarchy Process	MTTR	Mean Time to Repair
PM	Preventive Maintenance	MTTF	Mean Time to Failure
CBM	Condition Based Maintenance	QFD	Quality Function Deployment
TPM	Total Productive Maintenance	MIS	Maintenance Information System
CMMS	Computerized Maintenance Management System	TMM	Total Maintenance Management
RCM	Reliability-Centered Maintenance	DSS	Decision Support System
ECM	Effectiveness-Centered Maintenance	ECM	Electronic Counter Measures
SMM	Strategic Maintenance Management		

Figure 2: Classification of maintenance management literature in the medical equipment area by Garg and Deshmukh[31].

Maintenance Management Concept

One of the ways to achieve a proper understanding of the maintenance management concept is to check the elements that have formed the maintenance. According to the British Standards Organization, maintenance is «the combination of all technical, administrative and managerial measures during the life cycle of the item To maintain or restore it that can achieve/accomplish the desired performance»[49].

The importance of Maintenance Management in Healthcare Systems

Due to population growth in the current century, expectations and standards of living and also the demand for healthcare services have increased[50]. Also, the recent economic crises have led many organizations to reconsider their maintenance procedures with preserving quality levels to control costs.

The economic conditions of the healthcare industry in Iran face many problems since the government as the main sponsor of financing has encountered a lot of pecuniary difficulties. As it appears in Figure (3), in comparison to the leading countries in the healthcare industry such as France and Italy, Gross Domestic Product (GDP) as one of the most important indicators of the economic strength[51], is in poor condition in Iran[52,53].

According to the World Health Organization in terms of having an efficient healthcare system, Iran has the 93rd place out of 191 countries[53]. Therefore, given the current situation, it is a known fact that resources must be managed more efficiently.
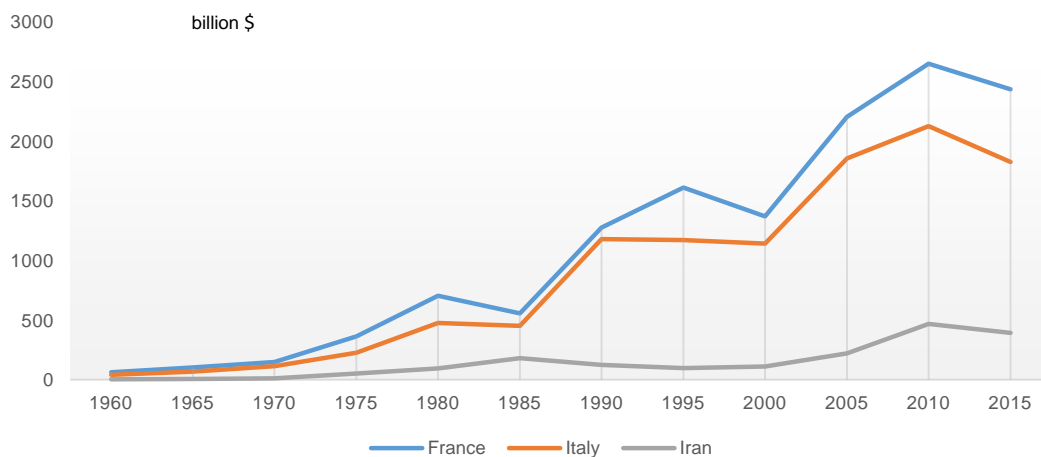

Figure 3: World Bank National Accounting Data and National Accounts Data Gross Domestic Product (GDP). 2018[54]

Based on the research carried out by the Health Management and Economics Research Center of Isfahan University of Medical Sciences, maintenance and repair costs account for more than 30% of the costs of each hospital bed per year[55]. on the other hand, a proper maintenance program can reduce costs by 45 to 50%[56].

Research Hypotheses and Questions

This study is accomplished with the three following assumptions:

- In the review process of manageable factors, the authors tried to avoid concentrating only on those factors that hospitals need to expand their financial resources for and examined other sources in Shahid Beheshti hospital and Ayatollah Rohani hospital in Babol both of which are public hospitals.

- Concepts such as organizational culture and leadership are not topics that can be quantitatively measured and so far, the authors have always looked for measurable factors such as 'the financial performance of a maintenance program'. This is the reason why the factors contributing to the improvement of the maintenance performance and the factors related to the improvements in the maintenance performance are mistaken with each other. One of the common errors observed in the literature review was "the inability of distinguishing/ differentiating between correlation and causation". Therefore, to understand the causality between the factors, tools such as Critical Success Factors (CSFs), Key Performance Indicator (KPI), Theory of Constraints & Current Reality Tree were used.
- Considering this fact that in statistical issues, the increase in the sample size leads to/ results in more accurate results, two hospitals are examined in this research.

The Research Gap
The research gap in the reviewed papers is not to consider causality alongside the correlation. This means the factors contributing to the improvement of the maintenance performance got mistaken with the factors that lead to the improvement in the maintenance performance. One of the observed common mistakes in the literature review was not to know the difference between correlation and causation and they considered them the same. In this research, there is an endeavor to fill this gap with the methods which will be described later.

Methods
There are two groups of data in this study. The first group is the information gathered from reviewed maintenance management articles and the second group, which focuses on two hospitals (Ayatollah Rouhani Babol and Shahid Dr. Beheshti Babol), and their current maintenance conditions. The second group includes three methods of collecting data:1) Questionnaire, 2) Observation and 3) Interview. The research steps are shown in figure (4).
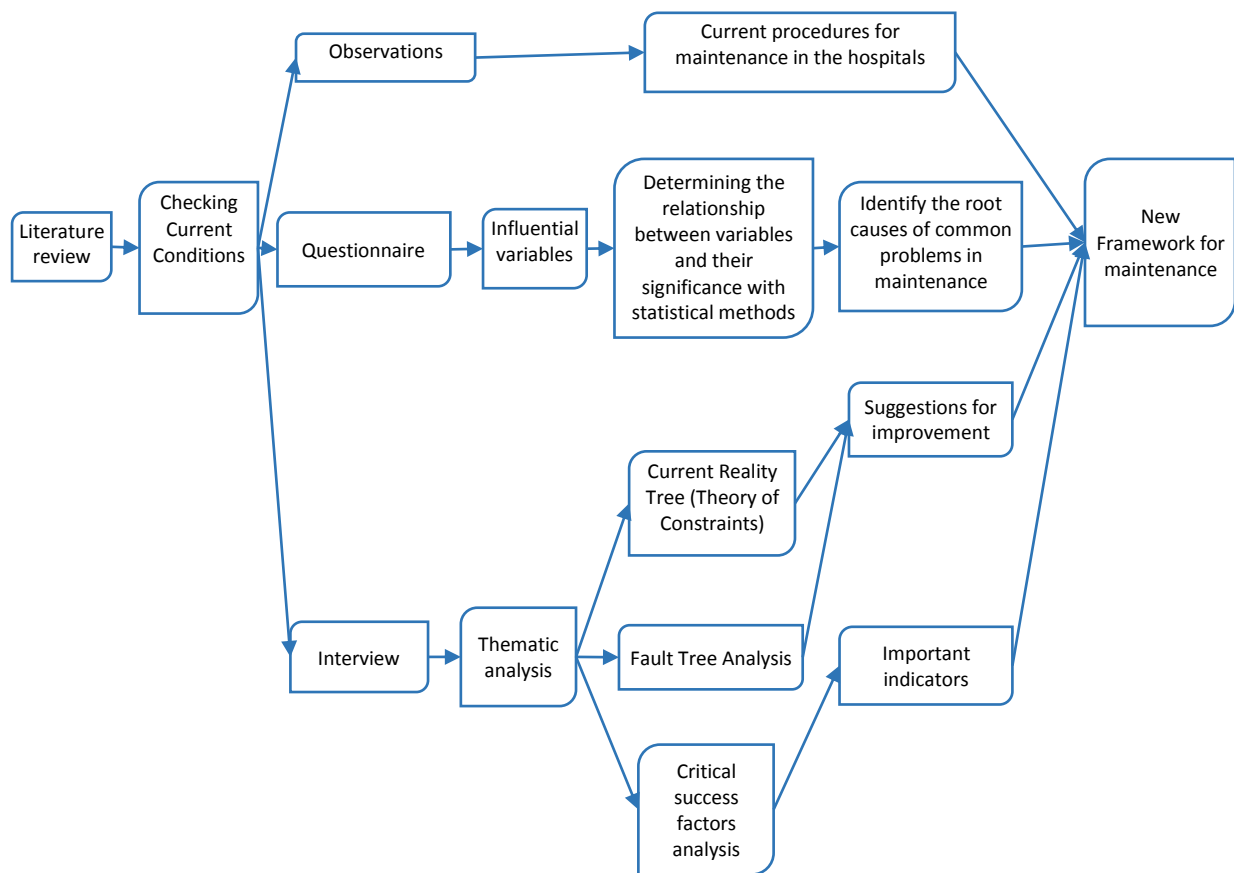
Figure 4: steps of research in Schematic shape

Sampling

In this research, statistical society includes the whole main equipment operators (supervisors) of those 2 hospitals. The sample size for both hospitals was 60 people using the Cochran formula for the finite population.

The nonprobability-available sampling was used to select the sample members, in a way that hospital supervisors were selected for sampling and they were 28 and 31 supervisors for Shahid Beheshti and Ayatollah Rouhani hospitals, respectively.

The obtained sample size using the Cochran formula (finite population) was 26 for Shahid Beheshti Hospital and 29 for Ayatollah Rouhani Hospital.

2 questionnaires were distributed in these 2 hospitals and there were 64 and 4 participants for questionnaires 1 and 2, respectively and the total efficiency of questionnaire 1 was 93.75. In other words, the total number of 60 questionnaires were received among 64 sent questionnaires. Also, for the second one, all 4 participants answered the questions. For the second questionnaire, the whole team of the maintenance department was 4 people (managers and engineers) and all of them participated in the process.

Designing Questionnaires

To design a questionnaire, based on literature review and analysis of hospitals' work environment and interviews with practitioners in the hospitals, important items were included in the questionnaires. The following items were considered in the design of the questionnaire:

- The questionnaire questions should be based on the research objectives or questions
- The questionnaire should attract the respondent and the questions should be appealing to him/her
- The questionnaire should be as short as possible and provide the data needed by the researcher.
- The questionnaire should be accompanied by instructions for completing it and explaining how to answer the questions for the respondent. The questionnaire completion instructions should be brief and contain all the information needed by the respondent to complete the questionnaire.

Based on the above, a preliminary questionnaire was designed. Then a preliminary study was carried out on it. The purpose of this study is to eliminate possible problems. Any corrections to the questionnaire will depend on the outcome of this preliminary survey. A preliminary survey should be conducted among the individuals who form the statistical population of the study. Respondents should be asked at the end of the questionnaire to comment on the clarity or ambiguity of some questions. If all (or most) of the respondents did not answer a particular question, such questions should be reviewed. Several questionnaire questions are usually considered to measure a particular variable. Therefore, it must be ensured that the answers to these questions measure the desired variable. To find out, the researcher can calculate the correlation between the results of the subjects' responses to each question and the individual's scores on the questionnaire. After all these analyses and assuring the validity and reliability of the questionnaire, the final text of the questionnaires was compiled and distributed among the target population.

Since the author in this section has sought to do anything but increasing the maintenance budget level to improve the performance, the questions were designed based on the five effective issues on improving maintenance performance entitled «external motivation», «policy and guidelines», «intrinsic motivation», «skill level», and «workload» as proposed by Peach et al[57]. The author further seeks to find each factor's impact rate on the maintenance performance and also more fundamental issues which could decay those 5 factors.

Two sets of questions are designed with a total of 56 questions. To make the questions more exploratory, five-point Likert-scale answers have been used that will help to answer questions more accurately[58]. Table (3) summarizes the questions that are designed according to each of these subjects.

Table 3: The relationship between extracted subjects and questions.

Extracted subjects from the literature review	Questionnaire 1	Questionnaire 2
External motivation	4-8-9-18-21	4-8-9
Intrinsic motivation	6-14	6-11-12
Policy and guidelines	5-8-9-10-13-17-19	8-5-9-10-14-18-19-21-22-24-25-26-27-28
Skill level	7-11-12-16	7-15-17-20-30-31
Workload	20	23
Others	1-2-3-15	1-2-3-33-34-35

The first questionnaire is intended to establish a detailed understanding of the actual repair condition of equipment operators in the hospitals in question. The second collection of questionnaires comprises of 35 questions intended to resolve care control problems. Two supervisors and two assistant managers included in the study.

Results

Based on the first questionnaire's responses, SPSS 25 software package was used to identify the potential relationships between equipment operator's performances and the current status of maintenance processes.

According to the type of questionnaire choices, the spearman's rank correlation coefficient method and Chi-square test were used. This is to determine if there are any two variables (questions) since the selection of the appropriate correlation coefficient for investigating the relationships between variables is influenced by the measurement scale of the variables (nominal, ordinal, interval, ratio), the «Spearman's rank correlation coefficient» method and «Chi-square test» were used.

Since in the Chi-squared test the relationship level is not detectable, the Cramer's V test was used instead to precisely understand the relationship.

For example, in response to one of the questions, it was found that 77 percent of the participants were only informed verbally about their equipment maintenance duties.

On the other hand, ambiguity and verbal informing were the reason for 50 percent of the people who claimed they were not encouraged to correctly performing the maintenance job.

For further analysis of understanding the relationship between the answers to these two questions, the Chi-squared test and Cramer's V test at significance level $\alpha = 0.05$ were used.

As you can see in table (4), the p-value is lower than the α and this shows a meaningful relationship between questions 6 and 9 in the α significance level. Also, Cramer's V value represents the relationship intensity.

Table 4 - Results of Chi-squared Pearson Cramer's V tests between questions 6 and 9 in Questionnaire 1.

p-value	Degrees of freedom	Amount	Test
0.007	16	33.112	Chi-squared
0.007	-	0.371	Cramer's V

In the statistics science, the reliability assesses the whole consistency of measurement and it will evaluate the internal consistency among items in a test[59]. According to Devellis, the minimum acceptable alpha should be 0.6, and as it is shown in table (5),

Cronbach's alpha in the first questionnaire was equal to 0.703 which was above the threshold value[60].

The second questionnaire did not require a reliability test due to the low number of participants (Four).

Table 5.Cronbach's Alpha in questionnaire 1

Cronbach's Alpha	No. of Items
.703	18

Factor Analysis

In this study, due to the systemic weaknesses which are identified in the responses to the questionnaires, 14 variables affecting maintenance management were initially identified. To decrease the number of variables to a manageable number in an accurate analysis, explanatory factor analysis is used for categorizing the variables.

The next problem is that each factor has been able to explain a few percents of the variance in the variables' set. Overall, 5 factors with greater than 1 Eigenvalues were able to explain 70.213% of the 14-item variance. Figure (5) shows the scree plot which helps to identify the key components[61].
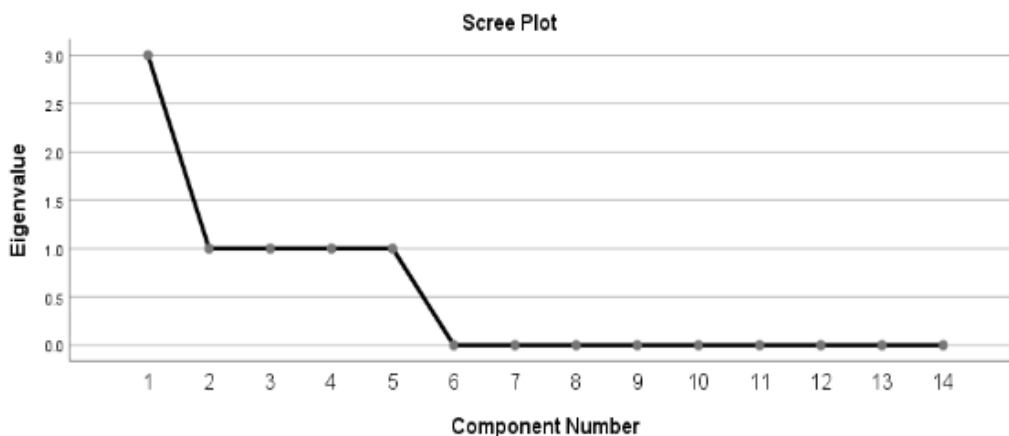
Figure 5: Scree Plot

Critical Success Factors

Concerning the five obtained components from the factor analysis, 12 critical success factors were suggested that in further studies, equipment operators and managers

were asked to identify their relative importance from their point of view and results are shown in Table(6).

By determining the Relative Importance Index (RII), these 12 factors are ranked. The RII is

calculated by the following formula (Equation 1)[62].

$$RII = \sum W / (A*N) \qquad (1)$$

Where W is the weight of each factor given by respondents (0 to 1); A is the highest weight, and N is the total number of respondents.

Theory of Constraints

"Theory of Constraints" is a systematic organizational concept, first formulated by Eliyahu M. Goldratt. The key point is to generalize the proposition that "the strength of a chain is as weak as its weakest link"[63]. This study uses the «existing reality tree» to identify major problems that may impede the maintenance management system's proper functioning.

The evidence gathered in this analysis was objectively evaluated in the context of the knowledge gained from interviews, community meetings, and findings. The key goal is to define possible limitations and obstacles to repair activities in the hospitals studied.

Current Reality Tree

As a first phase in the development of the Current Reality Tree (CRT), hospital engineers were invited to report on their background in maintenance operations. They were then challenged to pick the most adverse consequences (UDEs) on their jobs from the following list and the findings are 1-High Replacement Parts Price 2-High Pay for Repair Workers 3-Delay in Completion of Job 4-Frequent Failures 5-Equipment 6-Non-Compliance 7-Accumulation of Failures 8-Lack of consistency in government 9-Loss of opportunity for

creativity 10–Neglecting job place preparation 11–the reluctance of practitioners to carry out the skilled practice.

The second step consists of a representation of the cause and effect chart as a Current Reality Tree (CRT). The charts show that "failures' accumulation" is affected by five other inputs. The five feeder inputs are "lack of transparency in work policies", "lack of professionals capable of doing professional work", "Non-compliance", "low motivation" and "repeated failures". One can interpret from the charts that if all these inputs would happen, then the "errors" will accumulate. (Appendix 1)

Issues Classification

Any improvements to existing maintenance procedures would eventually need additional funding. For a deeper analysis, the problems are classified under three headings and their relevance has been investigated using restricted field studies: simple execution, small intervention costs, a strong effect on maintenance activities.

Suggested Changes to the Current Maintenance Process

The current maintenance control system is being reviewed in depth. As a consequence, numerous changes have been introduced to change the existing management procedures. The partnership between the director and the repair team is at the center of the revamped phase. This study also suggested a lack of stock discipline, ineffective quality monitoring, insufficient reporting and limited coordination between maintenance and warehouse departments. A significant share of medical devices in

hospitals is provided by charities and volunteers, and this criterion is largely dependent on the doctors' opinions or the supervisor of a particular section

of the hospital. by connecting them to the maintenance department, these valuable resources can be used more efficiently.

Table 6 - Divide the five key components of factor analysis into 12 critical success factors

RII	Critical Success Factor	Factor
0.59	Clear policies and procedures	Clarity of policies and procedures and appropriate training
0.68	Frequent training programs	
0.34	Determining tangible criteria for measuring the performance of maintenance staff	Staff Satisfaction and Competence
0.34	Establishing a system for encouragement and punishment according to the specified rules and agreed upon	
0.54	Use scrapped machines to train the trainees	
0.36	Get feedback from the staff	
0.68	Training	Correct and accurate failure detection
0.22	Promoting teamwork and sharing information and experiences	Current Strategy and Procedure
0.36	Increase the calibration frequency	
0.38	Relocating the maintenance office (Shahid Beheshti Hospital)	
0.59	Increasing the maintenance staff number	time
0.38	Accumulation of Errors	

Proposed Framework

According to the information gathered from the literature review, questionnaires, interviews, and observations, as well as the analytical methods such as critical success factors, theory of constraints and

improvement, can be summarized in four important principles. These four principles can form a useful framework with the lowest cost to improve the current maintenance management procedure in the hospitals which are under review in
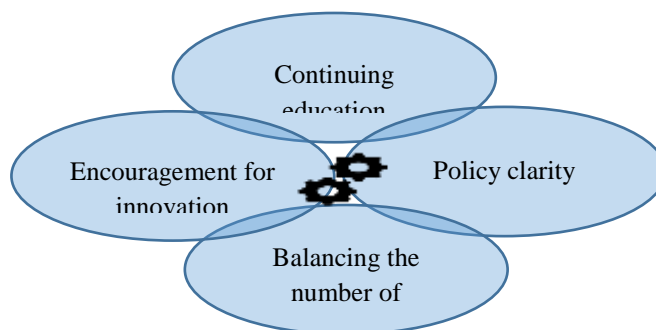
Figure 6- Proposed Framework for Improving the Maintenance Management Process in Current Situation

reality tree, the affecting factors on maintenance management

Due to clarity in business policies, device operators and maintenance staff

this paper's case study (Figure 6).

do not have specific tasks to follow (question 9 questionnaire 1). It was also found that the lack of

encouragement leads to a lack of motivation and problems in commitment, which causes the failures' accumulation. On the other hand, ineffective training was found directly related to failing to identify the failures (question 7 and question 12 from questionnaire 1). Along with all of these, maintenance staff believed that by increasing the personnel number and more training, there is no need to outsource the services.

Conclusions

One aspect of this analysis is to analyze existing maintenance management practices, recognize maintenance problems and assess their possible effects on maintenance activities in the hospital setting. Another step was to suggest a preventive management system for the healthcare sector in the circumstance under review.

In the implementation of repair plans from equipment operators, the group of supervisors is of considerable significance as they have the requisite power and impact over the corporate culture and decision-making mechanism in the hospital.

Employee improvement programs will be coordinated periodically to refresh the experience and expertise of maintenance workers at all levels (including contractors). This would potentially raise operational expenses in the short run, but in the long term, it will serve to boost the morale of workers and the efficiency of the equipment.

This research established daily maintenance control problems in the hospitals under investigation. The questionnaires were structured in line with the five proposed axes of the literature review. Based on the

findings of the questionnaire, five primary variables were established by factor review and grouped into 12 essential performance variables, so that their relative significance to maintenance workers and their jobs could be examined. The established healthcare system in the hospitals examined is then used as a case study. The updated maintenance system is intended to support healthcare systems (1) simplify and articulate their policies; (2) enhance reporting and access to information; (3) promote the tracking of events; and (4) allow more effective usage of maintenance services.

Suggestions for Future Studies

Since this research developed a comprehensive maintenance management framework, it is sufficiently general for applying to the healthcare organizations (particularly hospitals and clinics), it is necessary to conduct these studies in a large number of hospitals and medical centers. It is also recommended to study other types of hospitals, such as private ones.

Due to the conservative policies of the hospitals' managers, despite the maintenance management division's approval regarding the implementation of the results, sufficient conditions were not provided to execute the results of this study and to observe the before and after implementation changes.

Competing Interests

The authors declare no competing interests.

Authors' Contributions

The authors contributed equally to the writing of the article

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