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Assessment of the Maintenance Management in Hospitals of the Ecuadorian Institute of Social security of Zona 3 of Ecuador

Evaluación de la gestión del mantenimiento en hospitales del Instituto Ecuatoriano de Seguridad Social de la Zona 3 del Ecuador

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Abstract

The hospital infrastructure failures have an inestimable impact because they put human lives at stake. Therefore, potential risks contributing to the failure of medical equipment and hospital infrastructure must be identified, reduced or eliminated. The maintenance and its management constitute a tool that ensures the equipment performance. The aim of this work was to obtain quantitative data of the maintenance management at the hospitals of Zone 3 of the Ecuadorian Social Security system. The methodology consists of five phases: selection of assessment criteria, weighting of criteria, development of the assessment instrument, validation of the instrument by applying it to the four hospitals of Zone 3 in Ecuador and, at last, identification of low-performing aspects. Results demonstrate that the maintenance management of the hospitals in Zone 3 reached a quantitative average value of 55.5/100 points.

Resumen

Los fallos en la infraestructura hospitalaria tienen consecuencias inestimables debido a que involucra la vida humana, por lo que los riesgos potenciales que contribuyen al fallo de equipos médicos e infraestructura hospitalaria, tienen que ser identificados, reducidos o eliminados; para ello el mantenimiento y su gestión es una herramienta que se enfoca en asegurar el funcionamiento de un equipo. El propósito de este trabajo fue el obtener una valoración cuantitativa de la gestión del mantenimiento en los hospitales del Instituto Ecuatoriano de Seguridad Social de la Zona 3 del Ecuador. La metodología empleada consta de cinco fases, empezando por la selección de criterios de evaluación, ponderación de criterios, desarrollo del instrumento de evaluación, la validación del instrumento aplicándolo a cuatro hospitales de la Zona 3 del Ecuador; finalmente, la identificación de aspectos con bajo desempeño. Los resultados muestran que la gestión de mantenimiento de los hospitales de la Zona 3, alcanzaron una valoración cuantitativa promedio de 55,5/100 puntos.

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There are structural deficiencies that compromise the achievement of the maintenance department goals in three hospitals, yet there are viable processes that can be implemented to overcome such deficiencies and increase the level of fulfillment of requirements. It is concluded that the planning, programming and control of maintenance is the criterion with more potential to be improved.

Keywords: hospital maintenance, maintenance management, analytic hierarchy process, maintenance assessment, public health system.

En tres hospitales se evidencian debilidades estructurales que comprometen el logro de los objetivos del departamento de mantenimiento, pero existen procesos viables que pueden ser implantados para superar las deficiencias e incrementar el nivel de cumplimiento de las exigencias. Se concluye que la planificación, programación y control del mantenimiento es el criterio con más potencial para mejorar.

Palabras clave: mantenimiento hospitalario, gestión del mantenimiento, proceso analítico jerárquico, evaluación del mantenimiento, sistema de salud público.

1. Introduction

A high performance of the machines is requested in the industrial area, to avoid economic losses; nevertheless, failures in the infrastructure of hospitals may cause inestimable consequences, because it involves human life. A hospital is a complex structure constituted by medical and industrial equipment, and a multiform infrastructure that supports the provision of health services, which due to its importance requires that medical equipment do not present unexpected failures in their operation, that infrastructure provides a healthful and safe environment as an indispensable resource for doctors to ensure a good attention to patients, that correct diagnostics are generated, and even that the life of such patients is safeguarded.

This indicates that the potential risks that contribute to the failure of medical and industrial equipment and infrastructure, have to be identified and reduced, or as far as possible eliminated [1]. For that matter, the corresponding department has the maintenance and its management as a tool, that essentially focus in assuring the operation of equipment [2], either medical or industrial. According to Gonnelli *et al.* [3], the maintenance is an essential part of the life cycle of a medical equipment; however, the importance of the maintenance for the medical technology is not so known, and is only considered as a support activity [4].

In Ecuador, the health system is mainly constituted by public and private establishments [5]. The public system has more institutions (81.5 %) [6], and the Ecuadorian Institute of Social Security (EISS), that serves its affiliate population from 1970, is one of its constituting institutions. A ruling principle of the Ecuadorian social security system, is that it will work based on sustainability, efficiency, speed and transparence criteria [7]. According to the law of social security, efficiency should be understood as «the best economic utilization of the contributions and the other resources of the obligatory general insurance, to guarantee the timely delivery of enough provisions to its beneficiaries» [8]. Nevertheless, the economic problems faced by this institution for many years become evident in the type of attention provided to its users; the action in health attention is critic and inefficient, according to the president of the Directing Council of the EISS [9]. In addition, there are administrative problems with the hospital infrastructure due to lack of maintenance; in November 2018, the authorities of the EISS hospital in Cotopaxi expressed that the surgeries would be suspended because the sterilization equipment were not available due to lack of maintenance [10].

The availability of specialized medical equipment plays a fundamental role in the provision of health services; improving the maintenance of medical equipment in terms of effectiveness, reliability and availability, ultimately means improving the security of the patient and the user [3]]. According to a research carried out by Mwanza and Mbohwa, the main problems detected in a hospital related to maintenance, are the high unavailability of equipment and the no execution of the equipment maintenance according to the program established [11]. Since the quality of maintenance is key for providing a good medical attention to patients [12], it is necessary to evaluate its performance.

Gonnelli *et al.* [3] and Orozco *et al.* [13] indicated that measuring the performance of maintenance is a multidisciplinary process, and it is considered important for an organization because it is a tool that enables managerial decision making in a timely manner. Its objective tends to be misinterpreted, and the purpose is not judging the responsible people or questioning the results of their work, much less to sanction them, but identifying those aspects susceptible of being optimized [14], justify the investment made in maintenance [15] and avoiding that economic resources are wasted due to a deficient or inefficient maintenance [4]. The systematic evaluation enables assessing the performance of an organization of any area, and proposing the organizational and managerial changes to improve the system. Whether the results of the evaluation are negative or positive, the proposed strategies should aim to continuously improve, for the organization to operate successfully.

From 2014, an international accreditation process known as «Accreditation Canada International» (ACI) is conducted in Ecuador. Forty four public hospitals were evaluated [16], with the purpose of obtaining a certification that endorses the fulfillment of quality standards, and improve the attention in the different health centers. Among the hospitals evaluated according to organizational practices required by ACI, the hospital from Pastaza exhibits the lowest performance [17]. This hospital belongs to the planning zone 3 of Ecuador, constituted by the Cotopaxi, Tungurahua, Chimborazo and Pastaza provinces [18]. It is known that twenty one EISS hospitals have been evaluated by ACI up to 2018 [17], organism that employs an instrument to assess some aspects of hospitals maintenance management [19]. This is considered as positive, because the maintenance and its management constitute a tool that enables reaching the organizational objectives, and provide an essential contribution to the operating security of an element [2, 20], in this case hospital equipment and all infrastructure required for the appropriate functioning of a hospital.

In order to elaborate the evaluation instrument, it is necessary to determine a structure of evaluation criteria that enables to effectively assess the performance. That is a requirement used as a reference to compare the evidence found, while an evidence is the information that enables verifying and endorsing the fulfillment of a criterion [21]. In some cases, it has been found that it is required to breakdown the evaluation

criteria in sub-criteria [22,23]; these constitute rules to assess the fulfillment of the demands [24] established in the evaluation instrument, and contribute to assessing a criterion.

During the evaluation of the maintenance management of a hospital, the functional areas that articulate the maintenance management are determined; such areas include general organization of maintenance, human resources [11, 25], economic control, planning, maintenance programming and control, outsourcing [22], equipment inventory and criticality [26], maintenance documentation and availability of replacement parts in the department [11]. On the other hand, regarding maintenance, the Canadian accreditation system verifies the fulfillment of the existence of an implemented preventive maintenance program for all devices, equipment and medical technology [19], the generation of documented reports of preventive maintenance, the application of a process to evaluate the effectiveness of the preventive maintenance program, the documented tracking of the investigation of incidents and problems involving devices, equipment and medical technology, aiming to identify the causes of the failure.

According to what has been said, the purpose of this work is to design a method that enables the quantitative assessment of the maintenance management of hospitals, through answering the research question: how can the maintenance management be evaluated in hospitals?

Knowing the quantitative assessment of the evaluated criteria and sub-criteria, will enable the on time identification of improvement opportunities in the area of maintenance of hospitals; a methodology that allows attaining this objective is based on [27]: the selection and weighting of evaluation criteria and sub-criteria utilizing the Analytic Hierarchical Process (AHP) tool [20], which is employed to quantitatively prioritize evaluation criteria [23, 26, 27]; then, the development of an evaluation instrument, the validation of the method through the on-site evaluation of health institutions and, at last, the identification of criteria with lowest performance.

2. Materials and methods

A qualitative methodology was utilized to conduct this work. The methodological process is structured in five phases [27]:

1. Selection of criteria and sub-criteria for the evaluation of the maintenance management of hospital facilites.
2. Weighting of the evaluation criteria and sub-criteria.
3. Development of the evaluation instrument.
4. Validation of the method, through the evaluation of the maintenance management in the four hospital establishments of Zone 3.
5. Identification of low performance aspects.

2.1. First phase

Evaluation criteria and sub-criteria were collected from the literature review. Then, hospital maintenance managers of the zone, teachers from the Maintenance Engineering Department of the Chimborazo Superior Polytechnic School (CHSPS) and professionals with graduate studies in maintenance management were consulted, who assessed if the criteria and sub-criteria were adapted to the demands and context of the area under study, and identified and selected seven criteria and 20 sub-criteria. In addition, the objective of each sub-criteria was established in the following manner:

2.1.1. CS: Contraction of maintenance services

CS1 – Contraction policy: evaluate if there exist defined criteria under which the best contractor will be determined, who will be responsible of performing the works of both predictive and corrective maintenance, considering the experience of the contractor in years and in number of executed hospital maintenance service contracts.

CS2 – Supervision of maintenance works: verify if the hospital technical personnel supervises that the contractor fulfills the guidelines and criteria established in the maintenance services contracts.

CS3 – Technical specifications: guarantee that all the contracted maintenance activities are executed using materials and equipment that fulfill the established specifications, that the personnel that takes part has the stipulated expertise, and that the methodology defined in the service offer is followed.

2.1.2. HR: Human resources

HR1 - Training: assess if the training requirements needed by the maintenance personnel of equipment and hospital infrastructure have been defined, for them to complete their activities, and if a training plan has been established that enables the tracking of the percentage of fulfillment of the plan.

HR2: Professional training: determine if the personnel responsible of the department or area of maintenance of medical equipment and hospital infrastructure, has bachelor or master professional training related to the occupied position.

HR3 – Quantity of maintenance personnel: based on the number of delayed maintenance work orders, evaluate if there exist enough number of technicians to

carry out preventive and corrective maintenance activities that ensure the availability of both infrastructure and hospital equipment.

2.1.3. MI: Management of the inventory of the maintenance warehouse

MI1 – Items master: verify that the warehouse of replacement parts and materials for maintenance has an items master and, based on the opinion of the maintenance technicians, evaluate what percentage of such items master has errors in the items description, or if there is duplicate items or if the dispatch units are incorrectly assigned.

MI2 – Valued inventory of items: Confirm that the replacement parts and materials for maintenance are correctly valued, including the ones in the sub-warehouses.

MI3 – Control of stock: Confirm that the stock of replacement parts and materials for maintenance is under control, both in the main warehouse and in the sub-warehouses.

2.1.4. PP: Planning programming and control

PP1 – Maintenance indicators: determine how many indicators of the maintenance management, has been put into operation in the hospital.

PP2 – Maintenance plan: evaluate if there is a preventive maintenance plan, and the level of logistic planning of the maintenance tasks that constitute it.

PP3 – Programming of maintenance activities: establish the level of planning of logistic support in the process of programming the work orders of preventive and corrective maintenance.

PP4 – Risk-based criticality analysis: assess the complexity of the methodology, employed by the hospital to establish the criticality of the hospital equipment and infrastructure.

PP5 – Inventory of goods to be maintained: evaluate the percentage of hospital equipment and infrastructure that is coded and inventoried, and confirm if the code is physically located in the infrastructure and in each equipment that requires maintenance.

PP6 – Maintenance documentation: determine if the hospital possess the minimum maintenance documentation, such as work orders and material requisition. In addition, determine if maintenance indicators can be elaborated based on the information registered in such documents.

2.1.5. OM: Organization of maintenance

OM1 – Maintenance policies: assess if the hospital possesses maintenance policies, if they are updated and if they have been socialized with the hospital personnel.

OM2 – Computing tool for the maintenance management: establish if the hospital possesses a computing tool of type Computer-assisted maintenance management (CAMM), CMMS (computerized maintenance management system) o EAM (enterprise asset management), to administer the maintenance management and its degree of utilization.

2.1.6. EC: Economic control

EC1 – Maintenance budget: determine if the methodology employed to elaborate budgets of preventive and corrective maintenance of hospital equipment and infrastructure is technical and detailed.

EC2 – Percentage of fulfillment of the executed budget: evaluate the percentage of fulfillment of the maintenance budget of the previous year.

2.1.7. MC: Corrective maintenance

CM1 – Documentation and failure analysis, consequences and effects: evaluate if the important information about failures of hospital equipment and infrastructure is registered, and if analysis methodologies are applied to reduce its probability of occurrence.

2.2. Second phase

In order to determine the weightings of evaluation criteria and sub-criteria, the process method AHP developed by Saaty [28] was applied. It is used in research works whose objective is to prioritize alternatives [26, 29, 30], and has been employed in studies related with maintenance [23, 31]. The procedure can be summarized in four steps [28]:

2.2.1. Specification of the multicriteria decision problem

The hierarchical structure comprises three levels (Figure 1):

Level 1: indicates the objective of the application of the AHP technique, which in this case is to weight the evaluation criteria and sub-criteria.

Level 2: comprises the seven criteria that will be considered in the evaluation of the maintenance management.

Level 3: constituted by twenty sub-criteria that contribute to assess the evaluation criteria.

2.2.2. Construction of pair-wise ranking matrices

For the application of the AHP method, specialists related to the area under study were consulted considering three groups of interest related to maintenance and its management. The group of thirty specialists

was constituted by ten maintenance managers of hospitals in the zone, ten maintenance experts with master degree in the area and ten teachers of the Maintenance Engineering Department of the ESPOCH. The average experience in the maintenance area of these specialists is six years, who assessed the alternatives comparing them, according to the scale of the AHP method in Table 1.

With the assessment of the decision makers, pair-wise (by each decision maker) ranking matrices of the evaluation criteria and sub-criteria, respectively, were constructed. A pair-wise ranking matrix is a square matrix Anxn, where n is the number of criteria or sub-criteria, as the case may be, and they were constructed according to equations 1 and 2.

Table 1. Fundamental scale of comparison [32]

Value	Definition	Comments
1	Equal importance	Criterion A is equally important than criterion B
3	Moderate importancea	Importance and judgment slightly favor criterion A over criterion B
5	Big importance	Importance and judgment strongly favor criterion A over criterion B
7	Very big importance	Criterion A is much more important than criterion B
9	Extreme importance	The greater importance of criterion A over criterion B is indubitable
2, 4, 6 y 8	Intermediate values between the previous ones, when they are necessary	
Reciprocal of the previous	If criterion A is of big importance compared to criterion B, the notations would be the following: Criterion A in front of criterion B: 5/1 Criterion B in front of criterion A: 1/5	

$$A_{nxn} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (1)$$

$$A_{nxn} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{21} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{n1} & 1/a_{n2} & \cdots & 1 \end{bmatrix} \quad (2)$$

2.2.3. Calculation of the consistency ratio (CR)

It enables to determine if there are inconsistencies in the assessment of the decision maker. This index results from the quotient between the consistency index (IC) and the random consistency index (RCI), i.e.

$$CR = \frac{IC}{ICA} \quad (3)$$

The values of the random consistency index are established by the AHP method, and are a function of the size of the matrix (Table 2).

Table 2. Random consistency index [32]

Size of the matrix (n)	Random consistency index (RCI)
1	0
2	0
3	0,52
4	0,89
5	1,11
6	1,25
7	1,35
8	1,4
9	1,45
10	1,49

For calculating the consistency index (CI) it is necessary to know the value of $\lambda_{máx}$, and to obtain it matrix A was first normalized by means of the sum, obtaining the normalized pair-wise ranking matrix A_{norm}, applying equation 4, which results in equation 5.

$$\lambda_{norm} = \begin{bmatrix} \frac{a_{11}}{\sum_{n=1}^{n} a_{n1}} + & \frac{a_{12}}{\sum_{n=1}^{n} a_{n2}} + & \cdots + & \frac{a_{1n}}{\sum_{n=1}^{n} a_{nn}} \\ \frac{a_{21}}{\sum_{n=1}^{n} a_{n1}} + & \frac{a_{22}}{\sum_{n=1}^{n} a_{n2}} + & \cdots + & \frac{a_{2n}}{\sum_{n=1}^{n} a_{nn}} \\ \vdots & \vdots & & \vdots \\ \frac{a_{n1}}{\sum_{n=1}^{n} a_{n1}} + & \frac{a_{n2}}{\sum_{n=1}^{n} a_{n2}} + & \cdots + & \frac{a_{2n}}{\sum_{n=1}^{n} a_{nn}} \end{bmatrix} \quad (4)$$

$$A_{norm} = \begin{bmatrix} b_1 \\ 1 \\ b_2 \\ \vdots \\ \vdots \\ b_n \end{bmatrix} \quad (5)$$

From matrix A_{norm}, the vector B of global priorities is obtained as (equation 6).

$$B = \begin{bmatrix} \frac{b_1}{n}, & \frac{b_2}{n}, & \cdots & \frac{b_n}{n}, \end{bmatrix} \quad (6)$$

Then, the total row vector C is calculated as the matrix product A×B (equation 7).

$$A \times B = C = \begin{bmatrix} c_1, & c_2 & \cdots & c_n \end{bmatrix} \quad (7)$$

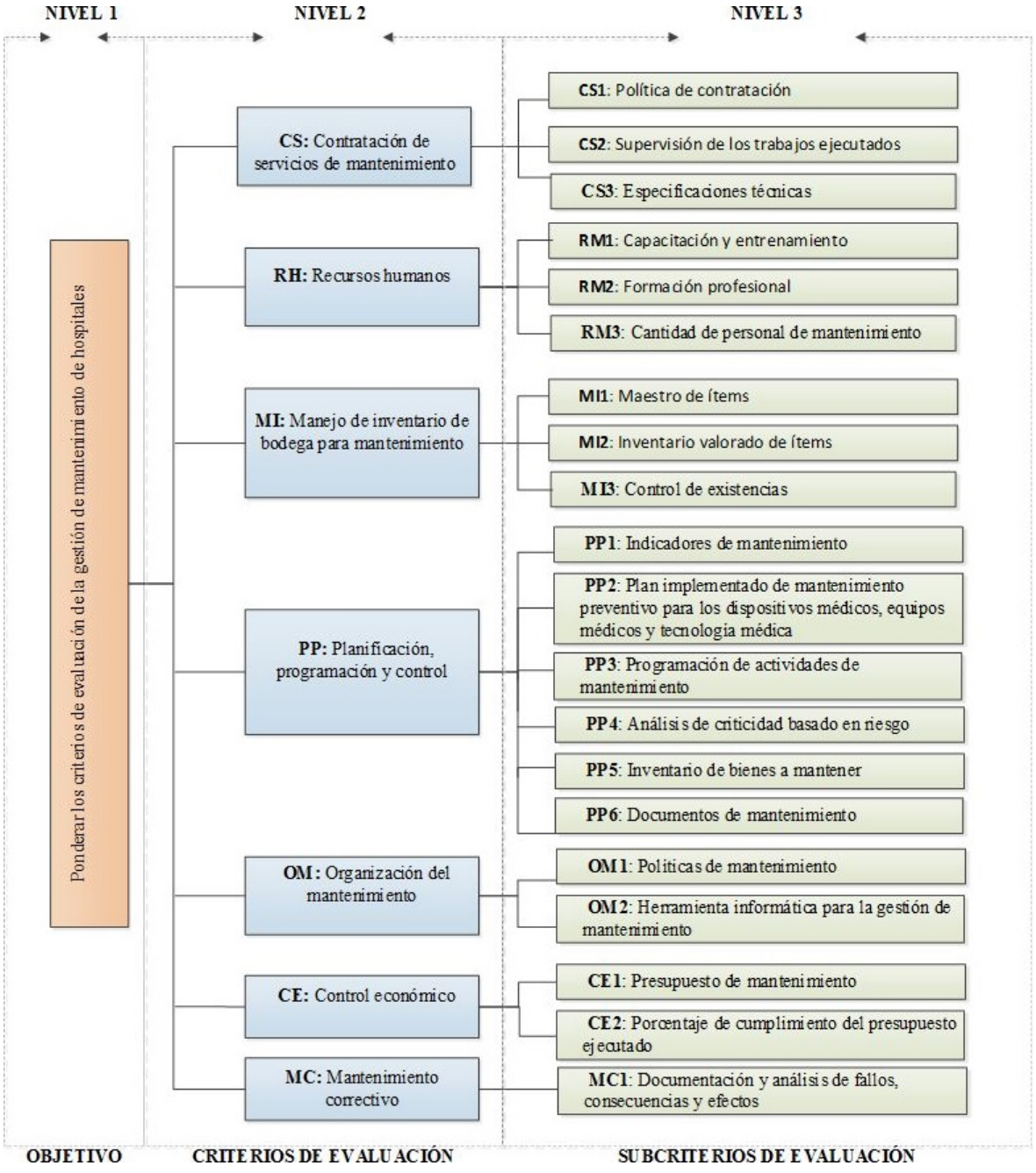


Figure 1. Hierarchical structure of the prioritization problem

Then the quotient between the corresponding elements of matrices C y B is calculated, resulting in the column vector D. The average of the elements of D gives the value of $\lambda_{máx}$, which is used to calculate the consistency index by means of equation 8.

$$IC = \frac{\lambda_{máx-n}}{n-1} \tag{8}$$

After the value of RC has been calculated for each decision maker, it should be verified that this value satisfies what is established by the AHP method; this value is a function of the size of the pair-wise ranking matrix, which for the case of the criteria (n = 7) should not exceed 10 % (Table 3).

Table 3. Maximum values of RC [32]

Size of the pair-wise ranking matrix (n)	Ratio of consistency (RC)
3	5%
4	9%
5 or greater	10%

2.2.4. Determination of the weighting factor of the evaluation criteria and sub-criteria

First, the eigenvectors were calculated employing the power method, determining the square A^2 of the pairwise ranking matrix, and then obtaining a column vector as the sum of the rows of the matrix resulting from the first product; this vector is further normalized by means of the sum and the first eigenvector V_{p1}Vp1 is obtained. The same procedure is followed to calculate the number of necessary eigenvectors, until it is verified that the corresponding elements of vectors V^{pn}, and V^{pn-1} are equal up to four decimal digits.

Since three groups of interest were consulted, the geometric mean [23] was employed to determine the final weighting of criteria and sub-criteria, thus consolidating the individual weightings for each decision maker first, and then by group of interest.

2.3. Third phase

As proposed by Quesada [33], the development of the evaluation instrument considers aspects such as:

- Description of the evaluation criterion
- Evaluation objective of the criterion
- Evaluation method
- Type of evaluation
- Reference levels
- Demands of the criterion
- Grade and assessment

According to the evaluation instrument, four reference levels were determined, which are qualitatively identified as insufficient, good, very good and excellent, with corresponding assessment of 0, 0.35, 0.7 and 1, respectively. The quantitative assessment enabled to define the performance threshold to which the qualitative assessment shown in Table 4 is linked.

2.4. Fourth phase

The validation of the evaluation method was carried out, by means of the application of the instrument developed for four EISS hospitals of the planning zone 3 of Ecuador. The hospitals are located in the province capitals, i.e. in the cities of Latacunga, Ambato, Riobamba and Puyo; the sampling was intentional since one of the hospitals in Zone 3 presented the lowest ACI accreditation performance [17].

Table 4. Scale of development assessment

Assessment		Description
Qualitative	**Quantitative**	
Insufficient	[0 % – 35 %)	Presents structural deficiencies that compromise the achievement of the objectives of the maintenance depart-ment.
Good	[35 % – 70 %)	Presents structural weaknesses that compromise the achievement of the objectives, but there exist viable processes that can be considered to improve.
Very good	[70 % – 100 %)	Presents nonstructural weaknesses that can be overcome through the improvement of the processes put into operation.
Excellent	100%	Fulfills all demands required by this evaluation method.

The hospitals in Riobamba and Ambato are classified as general hospitals, while the ones in Latacunga and Puyo are classified as basic. The average number of beds is 30, and all have a maintenance department. The evaluation was conducted on site based on the physical verification of evidences [21], which enables corroborating the affirmations of the respondent.

2.5. Fifth phase

The aspects of lowest performance were identified employing the technique of the Pareto diagram, which enabled the identification of alternatives to improve the obtained assessment.

3. Results and discussion

3.1. Results

As results of the first and second phase, and prior to the weighting of criteria, it was verified that each value of RC (Table 5) does not exceed the maximum limit (10 %).

Table 5. RC (%) values of decision makers by group of interest

N.°	Teachers of the Maintenance Engineering	Specialists in maintenance	Maintenance administrators
1	8	9,64	7,42
2	9,87	9,23	9,82
3	8,92	7,37	9,95
4	8,62	8,72	8,31
5	9,43	9,85	7,39
6	3,24	9,64	9,66
7	7,16	8,27	5,13
8	9,38	8,95	7,65
9	7,64	9,83	9,36
10	9,69	6,28	9,43

After the consistency in the assessment of the decision makers have been verified, the weightings for the evaluation criteria and sub-criteria shown in Table 6 were obtained.

The assessment instrument constituted by twenty evaluation sub-criteria, was developed in phase three. Table 7 shows an example with the sub-criterion OM2, and the adopted format structure for all sub-criteria, with levels of demand that vary according to each sub-criterion.

Using the evaluation instrument, and having defined the performance threshold, the evaluation of the maintenance departments of the four EISS hospitals – Zone 3 was conducted; the obtained results can be seen in Figure 2.

Table 8 indicates the global quantitative and qualitative assessments attained by the hospitals, while Figure 3 presents the sub-criteria that should be improved in each hospital; the grade that can be attained if such sub-criterion is improved is also indicated for each case.

Once the low performance criteria have been identified, it is necessary to establish an order of priorities to implant a plan of improvement actions, indicating the criteria on which such actions should be first taken to attain 80 % of the points lost in the evaluation (Table 9).

3.2. Discussion

In the phase of weighting the criteria and sub-criteria considered for evaluating the maintenance management, it resulted that the criterion «Contraction of maintenance services» is the most important (25 %) that should be evaluated in the administration, and therefore will have the greatest weight in the quantitative assessment, considering that the maintenance of approximately 90 % of the hospital equipment is carried out by external contractors. Inside this criterion, the sub-criterion to be considered is «Contraction policy», since it establishes the criteria for selecting the best offer that will execute the hospital maintenance activities.

With respect to the results obtained in the quantitative assessment, the EISS hospital of Latacunga exhibited the lowest performance; in the visit conducted for instrument application and on-site verification, it was evident that there was no responsible of the maintenance department designated by the maximum authority of the institution, and that the last responsible of such department did not have training at the bachelor level.

Table 6. Weighting of criteria and sub-criteria to evaluate the maintenance management

Criteria	Weights	Evaluation subcriteria	Weights
CS	0,25	CS1: Contraction policy	0,48
		CS2: Supervision of maintenance works	0,29
		CS3: Technical specifications	0,23
RM	0,18	RM1: Training	0,43
		RM2: Professional training	0,42
		RM3: Quantity of maintenance personnel	0,15
MI	0,17	MI1: Item master	0,46
		MI2: Valued inventory of items	0,28
		MI3: Control of stock	0,26
PP	0,13	PP1: Maintenance indicators	0,38
		PP2: Implemented preventive maintenance plan for medical equipment	0,18
		PP3: Programming of maintenance activities	0,14
		PP4: Risk-based criticality analysis	0,12
		PP5: Inventory of goods to be maintained	0,1
		PP6: Maintenance documentation	0,08
OM	0,11	OM1: Maintenance policies	0,78
		OM2: Computing tool for the maintenance management	0,22
CE	0,1	CE1: Maintenance budget	0,77
		CE2: Percentage of fulfillment of the executed budget	0,23
MC	0,06	MC1: Documentation and failure analysis, consequences and effects	1

This situation considerably affected the performance of the hospital, since the criterion «Human resources» is the second most important one in the as-

sessment, according to this method. On the other hand, the EISS hospital of Latacunga has the greater potential to improve (15.17 %). To quantitatively assess the maintenance management of the EISS hospitals of Zone 3, the average of the quantitative assessments obtained by each hospital was calculated, because when the hospitals were subjected to the certification process, they were evaluated with the same instrument and under the same criteria of the ACI, without considering its category; the instrument proposed here adopted the evaluation criteria of the ACI regarding maintenance. Therefore, the maintenance management in these EISS hospitals has an average of 55.5 points, with a standard deviation of 13 points.

Table 7. Description of the evaluation sub-criterion «Computing tool (software) for the maintenance management»

Evaluation sub-criterion: OM2 - Computing tool (software) for the maintenance management.		
Objective: Establish if the hospital possesses a computing tool of type Computer-assisted maintenance management (CAMM), CMMS (computerized maintenance management system) o EAM (enterprise asset management), to administer the maintenance management and its degree of utilization		
Evaluation method: Physical evidences of the installation and operability of the software are evaluated, for fulfilling the criterion demand		
Levels of reference	**Demands of the criterion**	**Puntuation**
Insufficient	It does not have CMMS/G-MAO (Computer maintenance management system) or has CMMS, but does not use it. Evidence: verify that CMMS is installed.	0
Good	The computing tool for maintenance management is an electronic sheet such as Excel, or a basic database such as Access.	0,35
Very good	It has CMMS and uses it to manage preventive maintenance. Evidence: maintenance plan emitted by the CMMS and preventive work orders emitted in the last 15 days.	0,7
Excellent	It has CMMS and uses it to calculate the indicators of the maintenance management. Evidence: report of costs, availability, mean time between failures and mean time for repairing.	1

Table 8. Global assessment of the performance of the EISS hospitals – Zone 3

EISS Hospital	**Quantitative assessment**	**Qualitative assessment**
General of Riobamba	77,8	Very good
Basic of Puyo	50,9	Good
General of Ambato	50,27	Good
Basic of Latacunga	43,05	Good
Average of the EISS hospitals of Zone 3	55,5	Maintenance management Level: Good

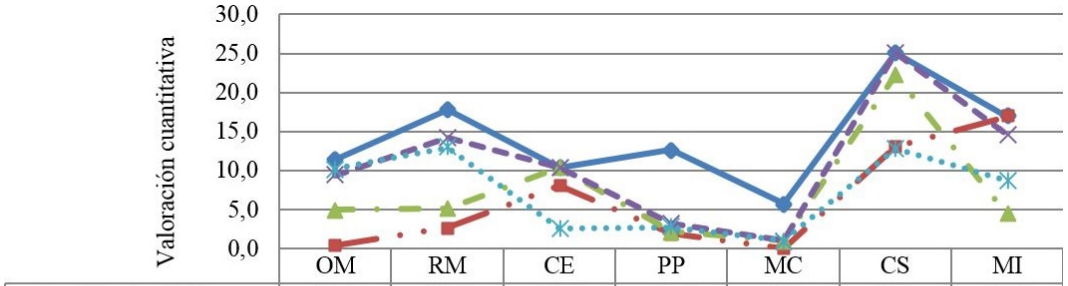
Table 9. Order of the criteria which require action to improve performance

EISS Hospital	**Criteria hierarchy to recover 80 % of the points lost**
General of Riobamba	1. Planning, programming and control 2. Corrective maintenance 3. Human resources
Basic of Puyo	1. Contraction of maintenance services 2. Planning, programming and control 3. Management of warehouse inventories
General of Ambato	1. Human resources 2. Management of warehouse inventories 3. Planning, programming and control
Basic of Latacunga	1. Human resources 2. Contraction of maintenance services 3. Organization of maintenance

One of the limitations of the method is that only the values established for each level of reference, can be assigned at the moment of assessment, i.e. no intermediate assessments can be given in case that one of the demands is partially fulfilled.

It is considered that this developed evaluation instrument can be applied to other hospitals, because all health centers possess an infrastructure that should be maintained to ensure a quality attention. The General Controlling Office of the State has a regulation about maintenance [34] that should be also fulfilled by the hospitals, regardless of their category.

This methodology not only provides a quantitative assessment, but it also indicates the order of the criteria on which action should be first taken to improve. Once the organizational changes have been proposed and put into operation according to the requirements of each sub-criterion, it is recommended to yearly conduct a new evaluation to the maintenance management, applying the same assessment instrument to quantitatively control the progress.



	OM	RM	CE	PP	MC	CS	MI
Nivel exigido	11,4	17,8	10,4	12,6	5,7	25,1	16,9
H. IESS Latacunga	0,4	2,6	8,0	2,0	0,0	13,1	16,9
H. IESS Ambato	5,0	5,1	10,4	2,1	1,0	22,2	4,4
H. IESS Riobamba	9,4	14,2	10,4	3,2	1,0	25,1	14,6
H. IESS Puyo	10,2	12,9	2,6	2,7	1,0	12,8	8,7

Figure 2. Desempeño de los hospitales del IESS – Zona 3, por criterio de evaluación.

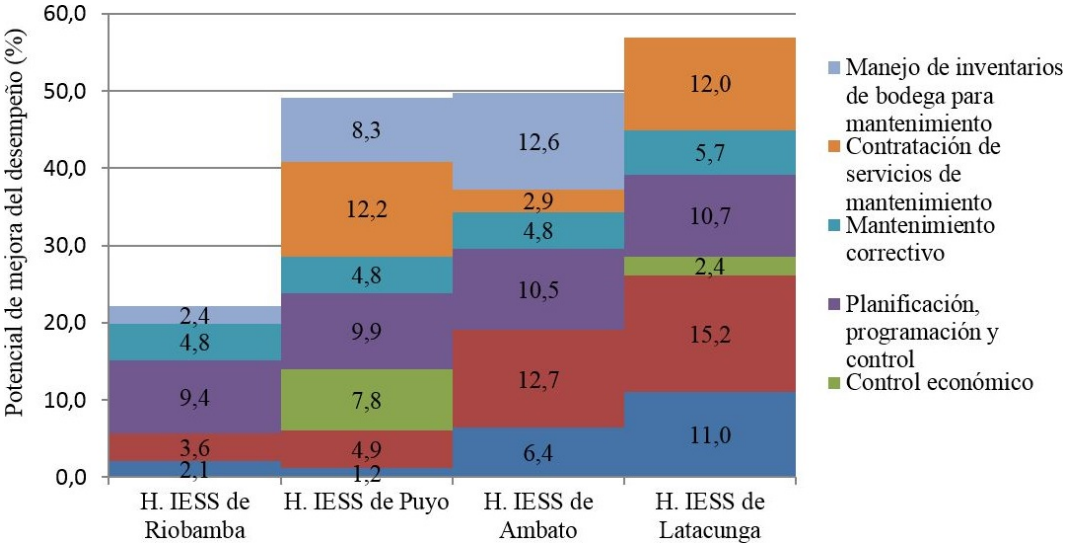


Figure 3. Identificación y potencial de mejora de los criterios con bajo desempeño.

4. Conclusions

The survey made to the specialists gave as a result, that the three most important criteria are the contraction of maintenance services (25 %), human resources (18 %) and management of warehouse inventories (17 %); this indicates that these are the evaluation criteria with more weight in the assessment.

It was identified that none of the hospitals has a performance according to the maximum level (desired level) of demand of the proposed method, and three of four hospitals that constitute the Zone 3 have a maintenance management level in the range (35 % – 70 %), which qualitatively represents a good maintenance management. This indicates that there are structural weaknesses that compromise the achievement of the objectives of the maintenance department, but there are viable processes that can be implemented to improve.

There exist four criteria in which the hospitals coincide that they should improve, even though each of them in different measure and sub-criterion. These criteria are: organization of maintenance; human resources; planning, programming and control of the maintenance and corrective maintenance.

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