Application Of Operational Reliability Tools In The Evaluation Of Buildings

Aplicación De Herramientas De La Confiabilidad Operacional En La Evaluación De Edificios

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ABSTRACT

As part of the investigation on the use of operational Reliability tools for the constructive technical evaluation of buildings, and after carrying out the first iteration in the adjustment of the Criticality Analysis, the Pareto Technique and the Impact Method, it was necessary to study the feasibility of application in built heritage. For the use of these tools, the component systems of the buildings to be evaluated were identified and the deterioration was surveyed through organoleptic inspections of each of the constituent elements. These adjusted methods were applied to the structural, non-structural and plumbing systems of three pavilions of the "Dr. Salvador Allende". Once these tools were applied, the characterization of each one by type of systems in the buildings was carried out, from which it turned out that the Criticality Analysis is better adjusted to the structural system, the Method of impacts to the non-structural system and the Technical from Pareto to the plumbing system.

Keywords: *criticality analysis, application of assessment tools, characterization of assessment tools, impact method, Pareto technique*

RESUMEN

Como parte de la investigación sobre el empleo de herramientas de la Confiabilidad operacional para la evaluación técnica constructiva de edificios y después de realizar la primera iteración en el ajuste del Análisis de criticidad, la Técnica de Pareto y el Método de los impactos, fue necesario estudiar la viabilidad de aplicación en el patrimonio construido. Para el empleo de estas herramientas se identificaron los sistemas componentes de los edificios a evaluar y se realizó el levantamiento de los deterioros a través de inspecciones organolépticas a cada uno de los elementos constituyentes. Estos métodos ajustados fueron aplicados al sistema, estructural, no estructural e hidrosanitario de los pabellones Manuel Valle, José Antonio Echeverría y Rubén Martínez Villena del Hospital Dr. Salvador Allende. Una vez aplicadas estas herramientas, se realizó la caracterización de cada una por tipo de sistemas en los edificios, de lo que resultó, que el Análisis de criticidad se ajusta mejor al sistema estructural, el Método de los impactos al sistema no estructural y la Técnica de Pareto al sistema hidrosanitario.

Palabras claves: *análisis de criticidad, aplicación de herramientas de evaluación, caracterización de herramientas de evaluación, método de los impactos, técnica de Pareto*

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1. INTRODUCTION

Operational Reliability, as a continuous improvement process, it has not been used for the evaluation of built heritage, despite systematically incorporating advanced diagnostic tools, analysis methodologies and new technologies to optimize the management, planning, execution and control of the maintenance [1]. These tools are very useful to determine the more or less critical state of any system, they can even be applied to elements as simple as required [2] [3].

The Criticality Analysis, the Pareto Technique and the Impact Method are Operational Reliability tools that are proposed for the technical evaluation of the built heritage [4] [5]. These are applicable to determine the level of criticality that each deterioration detected in the building presents, an indicator that is quantifiable and, therefore, establishes a hierarchy in injuries, which allows the analysis of each system based on frequency, impact and the detectability of damage.

The study is carried out at the Clinical Surgical Hospital "Dr. Salvador Allende", known as Quinta La Covadonga. This hospital complex was built by Spanish immigrants for the well-off segment of the population. The facilities were built within the late 1800´s and the early 1900´s, and although not the totality of the original buildings are in place today, some were rebuilt before 1930 [6]. The site is characterized by being made up of pavilions, which are generally differentiated depending by function, although there is architectural and construction uniformity throughout the complex, and the pavilions are considered to be of patrimonial value.

The long years of operating time that the hospital presents, together with other factors, has unevenly taken its toll in the technical construction state, bringing with it the deterioration of structural and non-structural elements and plumbing networks, as well as functional impairment in many constructions.

In this work, the constructive technical evaluation of three buildings with similar characteristics and construction status- the "Manuel Valle", "José Antonio Echeverría" and "Rubén Martínez Villena" pavilions- , will be carried out through operational reliability tools: Criticality analysis, Impact method and Pareto Technique adjusted for the evaluation of structural, non-structural and plumbing systems of buildings (master's thesis). With this evaluation it is intended to verify the applicability of the tools and their most convenient use depending on the component systems of the analyzed structure.

2. IDENTIFICATION AND CHARACTERIZATION OF THE COMPONENT SYSTEMS

2.1. Structural System

This system is formed by a set of structural elements connected to each other to form the load-bearing structure of a building (foundations, columns, beams, eardrums, load-bearing walls, slabs and stairs).

The existing construction system in the three pavilions is the traditional system, with load-bearing brick walls, a porticoed portal with reinforced concrete columns, and a roof slab of the same material. No structural element is hidden. The structural system has been divided into subsystems for a better understanding and management of information, namely: foundations, roof slabs, beams, load-bearing walls, columns and stairs. The basement will not be analyzed due to the fact that certain areas are access-restricted.

The type of foundation existing in the pavilions is unknown, but its evaluation will be carried out taking into account the behavior of the superstructure. The roof of the three pavilions is made with flat concrete slabs reinforced with steel bars, working in one direction (see Figure 1). The beams are made up of two steel I profiles that support bricks until they meet the roof slab on the perimeter of the building and have a depth of 0.50 m. The load-bearing walls were built with ceramic bricks placed citaron. The buildings have two types of columns, circular with a diameter of 0.47 m and square with a side of 0.53 m, in both cases made of reinforced concrete with steel bars and 5.10 m high, as shown in the figure. Figure 2, located in the portals that surround each one of them. building. There are a variety of stairs between the pavilions, but only those that give access to the roof and the main access on the ground floor of these will be analyzed. The Rubén Martínez Villena building has a metal boat staircase and the Manuel Valle and José Antonio Echeverría pavilions have reinforced concrete spiral stairs that allow access to the roof, as shown in Figure 3.

Figure 1. Reinforced concrete slab

Figure 2. Columns

Figure 3. Spiral staircase

2.2. Non-Structural System

Set of non-structural construction elements directly related to each other or in their function of constituting the enclosure and finishing of the building (roof, waterproofing system, carpentry, partitions, cladding and floors).

The waterproofing system of the three buildings is made up of asphalt blankets placed on the grilled and welding system, the original system of the pavilions. In the case of the José A. Echeverría pavilion, the raincoat is protected with aluminum sheets and in the Manuel Valle and Rubén Martínez Villena pavilions the blanket is protected with mineral granules. The carpentry is resolved with wood and glass, both in the interior and exterior doors and windows of the three pavilions. The partitions are built with ceramic brick and covered with plaster, and in the intervened areas with fine plaster. The finish is made up of several layers of water-based paint. In addition, there are veneers in the lower parts and in the wet areas of walls and partitions; In general, ceramic appears as a solution for this type of finish. In the paving solutions of the pavilions original mosaics from the time of construction are still preserved and in the intervened areas porcelain and marble slabs were used to finish off the floors.

Figure 4. Asphalt blanket with granules

Figure 5. Carpentry

Figure 6. Porcelain tile floors

2.3. Plumbing System

Set of elements related directly to each other or in their function of supplying drinking water and evacuation of rainwater and wastewater from the building (water tanks, pipes, pumping equipment, distribution system, sanitary furniture, sifas, collection systems, treatment and sewage disposal).

This system belongs to the non-structural part of the building, but the decision to separate the sanitary installation from the rest of the non-structural elements is given by the complexity and diversity of the elements that make up the hydraulic, sanitary and rainwater networks in a building. .

The hospital has cisterns in charge of the reserve for the water supply of all the areas, the pumping is carried out centrally, so the pavilions do not have a pumping system, only pipe drive for filling the elevated tanks . These compensation deposits are located on the roofs of the pavilions to guarantee the supply by gravity (Figure 7). In the three pavilions the distribution system is on the roof to feed the descending columns. Materials range from galvanized steel to polymers, used interchangeably in supply systems. The wet areas of the pavilions are made up of bathrooms and a pantry. Inside the bathrooms there are countertop sinks, drains, toilets (Figure 8) and shower cubicles. The Rubén Martínez Villena and Manuel Valle pavilions have a sink in the pantries. The evacuation system for water, rain and overflow from elevated tanks is through downpipes as shown in Figure 9, which are connected to the hospital storm drain for the three case studies.

Figure 7. Distributor and elevated tanks

Figure 8. Integral toilet

Figure 9. Downspouts

3. DAMAGE ASSESSMENT IN THE HALLS

The survey of deterioration was carried out from organoleptic inspections and based on the consultation of specialized bibliography on the subject. These inspections were carried out repeatedly on each of the roofs, facades and premises evaluated.

During the revisions, simple measuring instruments were used and the photographs taken reflected the conditions in which the inspected elements were found. To simplify data collection and processing, an identification code was created to assess the deficiencies of each system.

Similar deteriorations were observed in the systems inspected in the three pavilions, for a total of 125 lesions, 37 identified in the Manuel Valle pavilion, 48 in the José Antonio Echeverría pavilion and 40 injuries registered in the Rubén Martínez Villena pavilion. These are presented in table 1, organized by systems and pavilions. The generated codes are made up of the initial letter of the element or system to be evaluated and the deterioration identification number as shown below.

Table 1. Deteriorations identified by systems in each building

Sistems	Deterioration	Code	Pavilions		
			Manuel Valle	José A. Echeverría	Rubén Martínez Villena
Structural	Vertical and transverse cracks	C-01	x	x	
	Efflorescence	C-02		x	
	Loss of coating and exposure of reinforcing steel	C-03			x
	Abofamientos	L-01	x		
	Humidity stains	L-02		x	x
	Leaks	L-03		x	
	Loss of coating and exposure of reinforcing steel	L-04			x
	Cracks and fissures	V-01		x	
	Abofamientos	M-01	x		
	Pealed on wall	M-02	x		
	Humidity stains	M-03	x	x	x
	Leaks	M-04		x	
	Efflorescence	M-05		x	x
	Vertical crack	M-06		x	
	Plant life	M-07			x
	Loss of coating and exposure of reinforcing steel	E-01	x	x	
	Humidity stains	E-02	x		
	Metal object attached to the ladder for no apparent reason	E-03	x		
	Cracks and fissures	E-04		x	
	No step	E-05		x	
	Absence of railing	E-06		x	
Non-structural	Presence of damp, mold and waterlogging	SI-01		x	x
	Presence of vegetation	SI-02	x	x	x
	Poor adherence at the edges of the asphalt blanket	SI-04	x	x	x
	Bagging of water and/or air	SI-05		x	
	Deficiency in encounters with vertical elements	SI-06	x	x	x
	Accumulation of waste, materials and debris on the asphalt blanket	SI-18	x	x	x
	Presence of sharp objects on the asphalt blanket	SI-20		x	x
	Folds in the asphalt blanket	SI-21	x	x	x
	Cracks in asphalt blanket	SI-22	x	x	
	Detachment of mortar joints	SI-23	x	x	
	Loss, detachment, breakage or erosion of the clay slabs	SI-24	x	x	x
	Presence of vegetation in joints between clay slabs	SI-25		x	x
	Abofamientos or flaking	T-03	x	x	x
	Humidity stains	T-04	x	x	x
	Vegetation growth	T-05			x
	Stains on ceramic tiles	T-10	x	x	x
	Loss, breakage or detachment of ceramic tiles	T-11	x	x	x
	Wood chipping	CP-01	x	x	
	Glass breakage	CP-04		x	x
	No lock	CP-05			x
	Detached, blunt, cracked and/or scratched tiles	P-04	x		x
	Stains on tiles	P-06	x	x	x
Plumbing system	Tanks without lid	IH-01		x	
	Overflows of water tanks	IH-02		x	x
	Poorly covered tanks	IH-03			x
	Leaks between pipes and fittings	IH-05		x	
	Shower with leak	IH-06	x	x	
	Shower without arm and head	IH-07	x	x	x
	Faucet with spout	IH-08	x	x	x

4. APPLYING THE ADJUSTED TOOLS

In the study it was decided to apply the three tools to each of the component systems of the selected buildings, with the objective of determining which method is the most effective for the application in each type of system. The results obtained with each of the methods in the total number of systems analyzed are shown below.

4.1 Criticality Analysis

In the application of the Criticality Analysis tool, the frequency, impact and detectability indices were determined to determine the criticality index. As a result of this analysis, it was found that the most critical deterioration, of the total analyzed in the three pavilions, was IH-02 (Figure 10) with a criticality index equal to eight. The hierarchization of the deteriorations by systems analyzed showed that in the Manuel Valle building the deteriorations that stand out for their criticality index were "Damp stains" on walls and stairs, E-03 "Metallic object incorporated into the stairs for no reason apparent". ". It should be noted that although the damage with the highest criticality index results within the structural system of this pavilion, its value is four, so in none of these cases is it close to the maximum value of this index. The deteriorations with the highest indices of criticality in the non-structural and plumbing system of this building were P-04 (Figure 11), IS-06 "Failure of joints and unions" and IS-12 (Figure 12) in the sanitary network and IP -01 "Downpipes without protective balls" in the pluvial network.

In addition, the analysis was carried out, within this method, by the standard matrix for each pavilion, with which the criticality levels of the deteriorations identified in each building were determined (see Figures 13, 14 and 15).

The evaluation in the Manuel Valle Pavilion through the criticality analysis tool, showed that three of the deteriorations present high criticality, which represents 8.1%. These deteriorations were identified in the non-structural and plumbing system, specifically in the floors and in the sanitary installation. The state of deterioration of the floor slabs led to this classification of the injury "Detached, blunt, cracked and/or scratched slabs", identified as P-04. Injuries IS-06 “Failure of joints and unions” and IS-12 “Rupture in pipes” were classified as high level of criticality, mainly due to the impact that their existence generates in the building. In the cells corresponding to medium criticality, 13 deteriorations were located, for 35.1%; and 21 of the identified impairments present low criticality, which constitutes 56.8%.

The José Antonio Echeverría Pavilion, with the highest number of deteriorations of the three buildings, presented 6.3% of highly critical lesions, this value corresponding to lesions L-02 "Damp stains" on the structural slab, IH-05 "Leaks between pipes and accessories" in the hydraulic installation and IS-06 "Failure of joints and unions" of the sanitary network. Another 17 deteriorations were positioned in the medium criticality level cells and 28 obtained a low criticality classification.

Only one lesion with a high level of criticality was identified in the Rubén Martínez Villena Pavilion, P-04 “Detached, blunt, cracked and/or scratched slabs”, belonging to the floor subsystem. As medium criticality, 13 deteriorations appear and 26 are classified with a low level of criticality.

Figure 10. Overflow of water tanks

Figure 11. Detached, blunt, cracked and/or scratched tiles

Figure 12. Break in pipes

Criticality Matrix		Impact Index		
		1	2	3
Frequency Index	3	C-01; L-01; E-01; CP-01; IP-01; IP-02	P-04	
	2	M-01; M-02; E-03; SI-06; SI-24; T-03; T-10; IS-01; IS-02; IS-09	M-03; E-02; T-04; T-11; IH-13	IS-06; IS-12
	1	SI-02; SI-04; SI-18, SI-21; SI-22; SI-23; P-06; IH-07; IH-09; IS-04; IS-08	IH-06; IH-08	
Criticality levels				
A= 3 (8.1%)		M= 13 (35.1%)	B= 21 (56.8%)	

Figure 13. Criticality matrix of the Manuel Valle Pavilion

Criticality Matrix		Impact Index		
		1	2	3
Frequency Index	3	V-01; CP-01; P-06; IP-01	L-02	
	2	C-01; M-06; E-01; E-04; E-06; SI-21; SI-22; T-03; T-10; IS-01; IS-02; IS-09; IP-02	C-02; L-03; M-04; M-05; E-05; SI-01; T-04; T-11; IH-02; IH-06	
	1	SI-02; SI-04; SI-05; SI-06; SI-18; SI-20; SI-23; SI-24; SI-25; IH-01; IH-07; IH-09; IH-10; IS-03; IP-04	M-03; CP-04; IH-08	IH-05; IS-06
Criticality levels				
A= 3 (6.3%)		M= 17 (35.4%)	B= 28 (58.3%)	

Figura 14. Criticality matrix of the José A. Echeverría Pavilion

Criticality Matrix		Impact Index		
		1	2	3
Frequency Index	3	C-03; CP-05; IP-01	P-04	
	2	L-04; M-07; SI-06; SI-20; SI-24; T-03; IH-10; IH-12; IS-01; IS-02	L-02; M-03; M-05; T-04	
	1	SI-02; SI-04; SI-18; SI-21; SI-25; T-05; T-10; P-06; IH-03; IH-07; IH-09; IH-11; IS-05; IS-10; IP-02; IP-04	SI-01; T-11; CP-04; IH-02; IH-08; IP-03	
Criticality levels				
A= 1 (2.5%)	M= 13 (32.5%)		B= 26 (65%)	

Figure 15. Criticality matrix of the Rubén Martínez Villena Pavilion

4.2. Pareto Technique

In the application of the tool, the analysis was carried out by the frequency of occurrence of the identified deteriorations and by the impact they generate in the building, for which two classifications are obtained for the same injury and the category of damage was selected as a criterion. . higher criticality. It should be noted that this tool yields three categories A, B and C, but for the analysis and comparison with the rest of the tools, it is proposed to standardize category A at the High level of criticality (A), B at the medium level of criticality (M). and C at the low level of criticality (B). In the Manuel Valle Pavilion, the eight deteriorations identified in the structural system present a high level of criticality according to the Pareto technique, which represents 100%. More than 67% of the deteriorations identified in the non-structural system of this building were classified as highly critical and in the case of the plumbing system, 9 of the 14 existing deteriorations were classified as highly critical. The results obtained, for the José Antonio Echeverría Pavilion, through this tool, were: 11 deteriorations with high criticality in the structural system, deterioration of the non-structural system with a high criticality classification, 13, and 10 in the plumbing system of the 16 The deficiencies identified were highly critical. In the Rubén Martínez Villena Pavilion, the percentages of deterioration classified with high criticality based on the analysis of the Pareto technique are also high, behaving as follows: in the structural system 83% of the deterioration, in the non-structural system obtained 72% and in the plumbing system 81% of the total identified.

4.3. Impact Method

With the analysis of the technical, economic and functional parameters of the impact method, there were few deteriorations that obtained the classification of high criticality, prevailing those classified with the medium level. In the Manuel Valle pavilion, six of the deteriorations identified in the structural system obtained medium criticality out of a total of eight, while in the non-structural system nine were classified in this category and six with low criticality. Medium criticality also obtained 12 of the 14 deteriorations identified in the plumbing system.

In the structural system of the José Antonio Echeverría Pavilion, the classification was distributed as follows: four deteriorations with high criticality, eight with medium criticality and four with low criticality. In the non-structural system, 11 of the 19 lesions were classified with medium criticality and eight with low criticality. While in the plumbing system, the medium criticality classification prevailed in 12 of the 16 identified deteriorations and the rest remained low criticality.

In the Rubén Martínez Villena Pavilion, no deterioration was classified with high criticality based on the analysis with this method. Medium criticality obtained five deteriorations of the structural system of the six identified, 13 of the 18 found in the non-structural system and in the plumbing system nine of a total of 16 deteriorations were also classified in this category. The rest of the damage found in the building has low criticality. After carrying out the analysis applying the three tools, Table 2 was constructed to determine the disparity between the methods, which offers a vision of the applicability of the methods when comparing them.

Manuel Valle Pavilion				José A. Echeverría Pavilion				Rubén Martínez Villena Pavilion			
Deterioration (Code)	Criticality analysis	Pareto technique	Impact method	Deterioros (Code)	Criticality analysis	Pareto technique	Impact method	Deterioros (Code)	Criticality analysis	Pareto technique	Impact method
C-01	M	A	B	C-01	B	A	A	C-03	M	A	M
L-01	M	A	M	C-02	M	A	M	L-02	M	A	M
M-01	B	A	M	L-02	A	A	M	L-04	B	A	M
M-02	B	A	M	L-03	M	A	A	M-03	M	A	M
M-03	M	A	M	V-01	M	A	B	M-05	M	A	M
E-01	M	A	M	M-03	M	A	M	M-07	B	B	B
E-02	M	A	M	M-04	M	A	M	SI-01	M	A	M
E-03	B	A	B	M-05	M	A	M	SI-02	B	M	M
SI-02	B	B	M	M-06	B	A	A	SI-04	B	A	M
SI-04	B	A	M	E-01	B	A	M	SI-06	B	A	M
SI-06	B	A	M	E-04	B	M	A	SI-18	B	A	B
SI-18	B	A	B	E-05	M	A	M	SI-20	B	A	B
SI-21	B	A	M	E-06	B	M	M	SI-21	B	A	M
SI-22	B	A	A	SI-01	M	A	M	SI-24	B	A	M
SI-23	B	A	B	SI-02	B	M	M	SI-25	B	B	M
SI-24	B	A	M	SI-04	B	A	M	T-03	B	A	M
T-03	B	M	M	SI-05	B	A	B	T-04	M	A	M
T-04	M	A	M	SI-06	B	A	M	T-05	B	M	B
T-10	B	M	B	SI-18	B	A	B	T-10	B	M	B
T-11	M	A	M	SI-20	B	M	B	T-11	M	A	M
CP-01	M	M	B	SI-21	B	A	M	CP-04	M	A	M
P-04	A	A	M	SI-22	B	A	A	CP-05	M	A	M
P-06	B	B	B	SI-23	B	A	B	P-04	A	A	M
IH-06	M	A	M	SI-24	B	A	M	P-06	B	M	B
IH-07	B	M	M	SI-25	B	B	M	IH-02	M	A	M
IH-08	M	A	M	T-03	B	A	M	IH-03	B	A	B
IH-09	B	M	M	T-04	M	A	M	IH-07	B	A	M
IH-13	M	A	M	T-10	B	M	B	IH-08	M	A	M
IS-01	B	M	B	T-11	M	A	M	IH-09	B	A	M
IS-02	B	M	M	CP-01	M	M	B	IH-10	B	A	B
IS-04	B	M	M	CP-04	M	A	M	IH-11	B	M	B
IS-06	A	A	M	P-06	M	M	B	IH-12	B	A	M
IS-08	B	A	M	IH-01	B	B	B	IS-01	B	M	B
IS-09	B	A	M	IH-02	M	A	M	IS-02	B	M	M

Manuel Valle Pavilion				José A. Echeverría Pavilion				Rubén Martínez Villena Pavilion			
Deterioration (Code)	**Criticality analysis**	**Pareto technique**	**Impact method**	**Deterioros (Code)**	**Criticality analysis**	**Pareto technique**	**Impact method**	**Deterioros (Code)**	**Criticality analysis**	**Pareto technique**	**Impact method**
IS-12	A	A	M	IH-05	A	A	M	IS-05	B	A	B
IP-01	M	A	B	IH-06	M	A	M	IS-10	B	A	B
IP-02	M	A	M	IH-07	B	A	M	IP-01	M	A	B
				IH-08	M	A	M	IP-02	B	A	M
				IH-09	B	M	M	IP-03	M	A	M
				IH-10	B	B	B	IP-04	B	A	M
				IS-01	B	M	B				
				IS-02	B	M	M				
				IS-03	B	M	M				
				IS-06	A	A	M				
				IS-09	B	A	M				
				IP-01	M	A	B				
				IP-02	B	A	M				
				IP-04	B	A	M				

5. CHARACTERIZATION OF THE ADJUSTED TOOLS

During the application of the tools, non-positive aspects that interfered or made the analysis more complex in certain building systems were identified, for which the characterization of each of the methods was carried out from the application to the studied systems. This characterization was carried out on the basis of the analysis of the results obtained and the reality of the deteriorations identified in the inspections; In addition, a survey was carried out on the students who were in charge of the application of the tools in each type of system, as research for their Diploma Work directed by the author, since there are no specialists who have used these tools for evaluation. of buildings. For this characterization, a non-probabilistic sampling was designed, based on the judgment of the person in charge of the investigation.

Variables

- Ease of understanding
- Level of knowledge for the application
- Level of incompatibility with the data
- Difficulty for data categorization
- Level of complexity in the application
- Level of laboriousness in data processing
- Limitations in the results of the tools
- Ease of interpreting the results
- Irrelevance of the results

The analysis to determine which of the applied tools is the most convenient is carried out through the arithmetic mean, to determine the average in the convenience values. The scales were framed between 0 and 10, from the easiest and simplest to the most difficult and complex, therefore, as the arithmetic mean of the variables decreases its value, it will be more convenient for the analyzed system, instead, it will be less desirable as its value increases.

From the analysis of the convenience of applying the adjusted tools, it was possible to conclude that, for the structural system, the Criticality Analysis is the most convenient method with an arithmetic mean of 4.8 (see Figure 16), since for the student it was easier to understand, with less difficulty for the categorization of the data, with fewer limitations in the result and greater ease for its interpretation, with respect to the other tools.

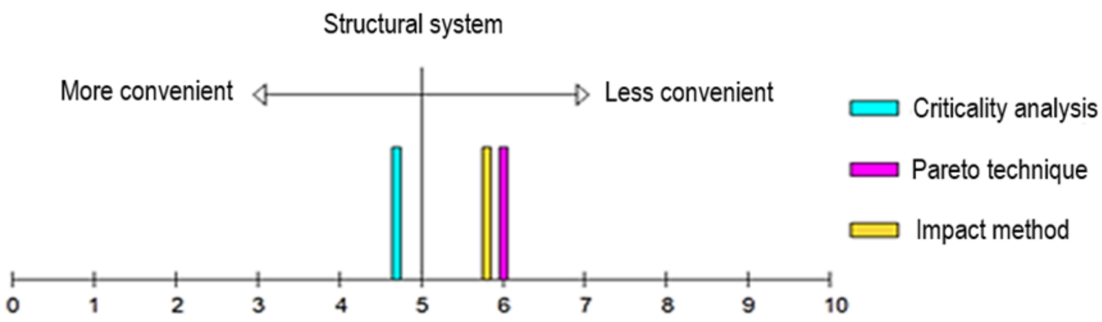

Figure 16. Convenience graph for the structural system

The Impact Method turned out to be the most convenient tool for the non-structural system with an arithmetic mean of 3.33, at the discretion of the student in charge of this system (see Figure 17). It was the method that is easier to understand, the one that requires less preparation prior to its application, little incompatibility with the data taken in the inspections, lower level of complexity, less laborious, the one that offers the most scope in its results, these being easy. to interpret.

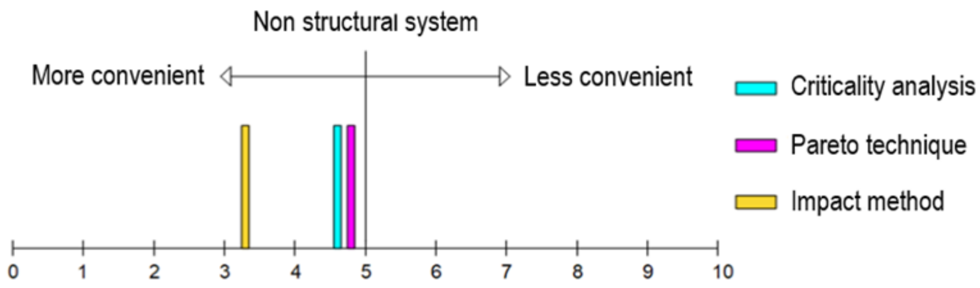

Figure 17. Convenience graph for the non-structural system

The most convenient tool for the plumbing system turned out to be the Pareto Technique with an average of 4.3, because according to the student, when processing the data, this method was easier to understand, required less preparation prior to its application, little incompatibility with the data taken in the inspections, lower level of complexity, less laborious, more scope offered in its results, these being easy to interpret the graph shown in Figure 18

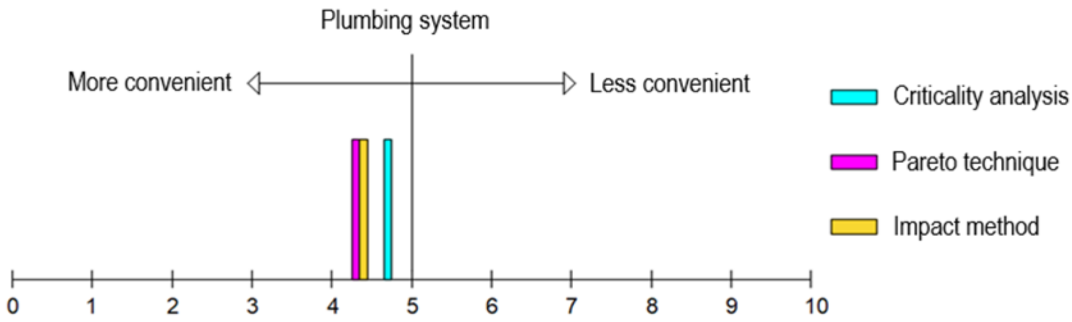

Figure 18. Convenience graph for the plumbing system

On the other hand, the comparative analysis of the results of the application of the tools was carried out, which, for the structural system, had the highest percentage of coincidence, with the Criticality Analysis and the Impact Method, which led to the decision to select the Criticality Analysis that allows the hierarchization and classification by levels of criticality, in addition to the results of the survey carried out to the evaluator in charge of this system.

In the non-structural system, the Criticality Analysis and the Impact Method tools also had the highest percentage of coincidence. In this case, the impact method was chosen, since it is less laborious and valid for this type of system, in addition to the criteria evaluated in the survey of the evaluator on the tools.

The tools that had the highest percentage of coincidence in the plumbing system were the Criticality Analysis and the Impact Method, but the Pareto Technique is considered relevant, based on the application, the criteria granted by the surveyed evaluator and the characteristics of lesions in this system, that for most, the frequency of occurrence can be determined by counting; In addition, according to this technique, deterioration with category A (high criticality) represents around 20% of the causes that cause 80% of the greatest impacts.

6. CONCLUSIONS

The adjusted tools proved convenient for the evaluation of building component systems. From its application it was possible to verify that the Criticality Analysis is the tool that best adjusts to the conditions of the structural system, the Method of impacts to the non-structural system and the Pareto Technique to the plumbing system. These analyze parameters, not only of a constructive nature, but functional, economic, sanitary and environmental, however, since it is the first time that they have been used in this sector, it is considered opportune to continue the study in the adjustment, so as to guarantee the greatest possible precision in the results.

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