MAINTAINABILITY REQUIREMENTS IN THE PERFORMANCE OF MAINTENANCE SERVICES

Rui Paulo Dias Muniz
Production Engineering Postgraduate Program
Universidade Federal do Rio Grande do Sul - UFRGS/PPGEP
rui.muniz@ufrgs.br

Fernando Gonçalves Amaral
Production Engineering Postgraduate Program
Universidade Federal do Rio Grande do Sul - UFRGS/PPGEP
amaral@producao.ufrgs.br

André Luis Korzenowski
Faculdade São Francisco de Assis - UNIFIN
Pontifícia Universidade Católica do Rio Grande do Sul – PUCRS/FAMAT
Universidade Federal do Rio Grande do Sul - UFRGS/PPGEP
andre@korzenowski.com

Abstract
Maintainability requirements, which are responsible for the conformity in the performance of maintenance services, ensure the improvement of the organizational results and the adequate conditions for the performance in the matter of environment, safety and health. These are ergonomic aspects which preserve the integrity of the assets and the well-being of the working crew. To an effective characterization of these requirements, it is necessary to go beyond the literature research and check the perception of experienced maintenance performers about their considerations and repercussions for the conformity of maintenance services. The study aims to investigate towards maintenance experts the importance and applicability of the identified maintainability requirements, as well as to qualify them on emergency, so to establish a preference for the implementation of improvements and innovation in the processes of performance of maintenance services, which will present consequences on the organizational results.
Keywords*:* Reliability. Ergonomics. Results. Safety. Health.

INTRODUCTION

Service, in a legal language, regarding rights and responsibilities, denotes the performance of any intellectual or material activity with lucrative or productive ends (Diniz, 1998). From this statement, in a conjuncture of fast economic and technological transformations, it is reasonable to affirm that the processes and activities are in continuous changes, requiring capacity of innovation and constant improvement.

About the service innovation, according to Vargas & Zawislak (2006), it results from the adoption of technological innovations developed in the capital goods production section. This way, the analysis of service innovation is not the analysis of an innovation process itself,

but the appreciation of the process of industrial technological innovation spread in the service department. Thus, Vargas & Zawislak (2006) classifies the types of service innovation in four groups: product, process, management and market. The product innovation is related to the delivering of a new service; process innovation is concerned with the modification of prescribed procedures to the elaboration/production of a service (back office) or procedures of user/customer assistance and service delivery (front office); the organizational or management innovation is related to the introduction of new managing tools or management patterns; and market innovation is associated to the discovery of brand new markets, to the identification of niches within the same market, or, yet, to the behavioral change of the organization in the market in which it takes part.

On the matter of improvement, Andrade (2005) states that quality in the services department might be improved through simple measures, such as: focusing on new tools like service marketing; informing the customer about the quality of the services performed, in order to raise an adequate expectation; defining service patterns that can be evaluated; planning the customer assistance systems; and informing to the company's employees what quality patterns are supposed to be sustained.

As a service, maintenance is supposed to pay attention to the innovations and improvements, particularly in relation to prescribed procedures, patterns establishment and planning of activities and tasks. It denotes the preoccupation with the performance of maintenance services, phase in which the results of the execution present consequences on reliability and availability of the system or equipment upon which the work is being made. The program of the demanded services and the auxiliary processes of logistics, resources, infrastructure, conditions and means, tangible to the maintenance activities, will be connected to the environment, to people, to the capacity and results of organizational policies and investments.

Concerning maintainability, in relation to the conformity conditions in the performance of maintenance services, it is the ensuring element for systemic reliability, associated to efficiency, accuracy, reliability, and availability markers. In addition to include human-factor related aspects, such as health, safety, capacity, proficiency, and disposition, it is also correlated to facilities, environments, resources and logistics, which are affected by the physical structures.

Considering this view and the particular demands of the maintenance processes, the recognition of maintainability requirements in search for its improvement, approached by Muniz & Amaral (2010a; 2010b; 2010c), in their articles *Maintainability: From the Task to the Organizational Results*, *Maintainability and Strategy in the Organizations*, and *Maintainability Requirements*, leads to the necessity of investigating the perception and consideration of maintenance professionals about the requirements found in literature.

The purpose of the study is to verify, by practice, whether the recognized maintainability requirements are able to ensure the conformity in the performance of maintenance services. It aims, so, to found a reference of necessary markers to maintainability improvement, assisting the management of elimination and decreasing the intervals of equipment maintenance. To this end, a research was constructed with maintenance professionals, experienced in the study activities, maintenance management, command and performance, who were denominated in the study Maintenance Experts. Thereby, the study verified toward the maintenance experts the importance and applicability of maintainability requirements in the performance of maintenance services described by Muniz & Amaral (2010c). Going further, it discussed the existent relation between the detected issues in literature and the evaluation of the maintenance experts, instituting a preference about the requirements to be developed in an improvement or implementation achievement by an organization. This way, the certainty of a better conformity in the processes of maintenance services is expected.

METHODOLOGICAL PROCEDURES

Were considered for the present article the studies developed by Muniz & Amaral (2010a; 2010b) in the articles *Maintainability: From the Task to the Organizational Results* and *Maintainability and Strategy in the Organizations*; equally, were adopted for this study the forty-nine maintainability requirements defined in the article *Maintainability Requirements* (Muniz & Amaral, 2010c).

In order to fulfill the goal of the study, it was built the research *Maintainability Requirements: Experts' Analysis*, forwarded by internet to one hundred and thirty-two maintenance professionals. These subjects are considered as maintenance experts, experienced in study activities, management, command, and performance of maintenance. The identification of the experts was made through the insertion, acknowledgment, and technical remarks of these professionals in the academic and market environments, covering

different sections of economy. Before its application, the research was tested through interviews, according to all the established guidelines for its application. In the test, were considered the applied method, the answerer's understanding, facilities, time of answering, conformity of goals, and presentation.

The research, divided into quantitative and qualitative, intended to identify the valuation attributed by the expert to the importance and applicability of each requirement and considerations of the specialists on maintainability requirements in the performance of maintenance services. Figure 1 presents the relation of the stratified requirements by section, where the maintenance experts were oriented to attribute continuous values from 1.0 to 10.0, from lowest to highest importance and applicability, respectively, in accordance with their understanding about the importance and applicability of the mentioned maintainability requirements for the performance of maintenance services. In relation to the qualitative issue, it was possible to the maintenance experts to register their reflections about the subject in the field Considerations of the Expert about Maintainability Requirements in the Performance of Maintenance Services. In that field, no regulation for answering was established.

Section	Requirement	Importance	Applicability
Environment	Simple and Safe Access		
	Basic Necessities Attendance		
	Consideration of Climatic and Environmental Restrictions		
	Durability of Systems and Equipment under Environment Conditions		
	Generation of detritus and fluids		
Empowerment	Attitude and Responsibility Capacities		
	Empowerment and Capability Policy		
	Proactiveness in Performance		
	Tradition Breakage		
Management	Benchmark in Practice		
	Dislocation Decrease		
	Pause Management		
	Repairing Action Impact		
	Clear, Concise, and Easy Comprehension Information through all Activities		
	Previous Arrangement of Work		
	Planning of Replacement Pieces and Modules		
	Maintenance Policy		
	PCM Related to the Lifetime		
	Experiences Registry		
	Criticism Rules for Planning		
	Services and Inspection Report		
	Maintenance Supervision		
	Common, Classical and General Domain Techniques		

Figure 1 – Table of maintainability requirements

The contextualization of the problem was set from the consideration that there is not the necessary normalization to maintainability, which ensures the attendance of facilities in the performance of maintenance functions by the observation of requirements. This condition was referred to the definition of maintainability of NBR Norm 5462/1994 – Reliability and Maintainability, where it is the capacity of an item to be maintained or rearranged to be capable of performing its required functions, under specified conditions of use, whenever the maintenance is performed under determined conditions and by means of prescript procedures and instruments. The requirements were identified by sections in Environment, Empowerment, Management, Infrastructure, Safety and Technique.

The statistic analysis adopted to verify the existence of significant differences on the opinion of the interviewed for each requirement was the Variance Analysis (ANOVA) with blocking. In this case, to correct the dependence effect amongst the evaluation of each requirement by each subject, the analysis considered the interviewed individual as a block. In order to investigate the supposition of homoscedasticity, or variance equality amongst the groups, the Levene's test was applied, and when necessary, a data transform was applied. When ANOVA presented significant results amongst the Requirements, the Post Hoc LSD test was implemented for the execution of Multiple Comparison.

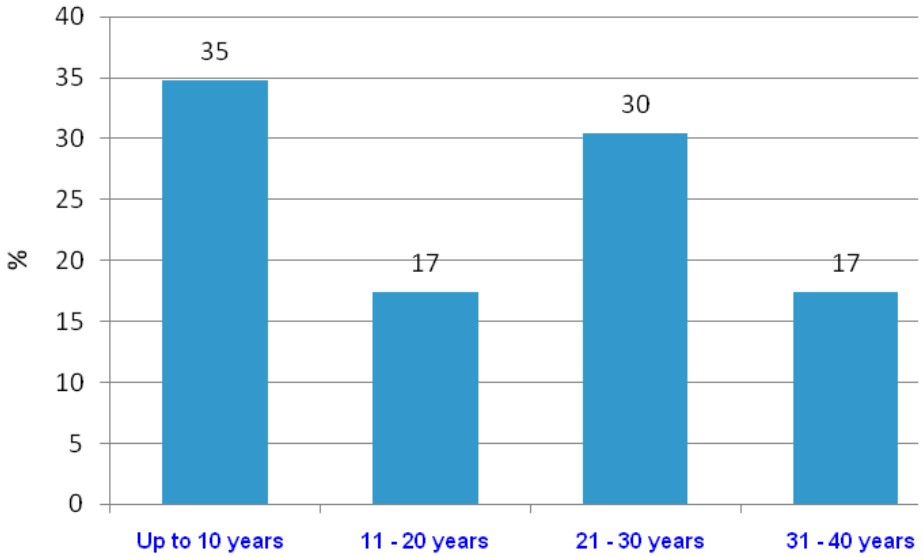
The resultant analyses from the information produced by the research are presented in the conclusion of this article, where it displays a philosophical model to the considering of groups of maintainability requirements to be firstly recognized in the organizations.

RESULTS

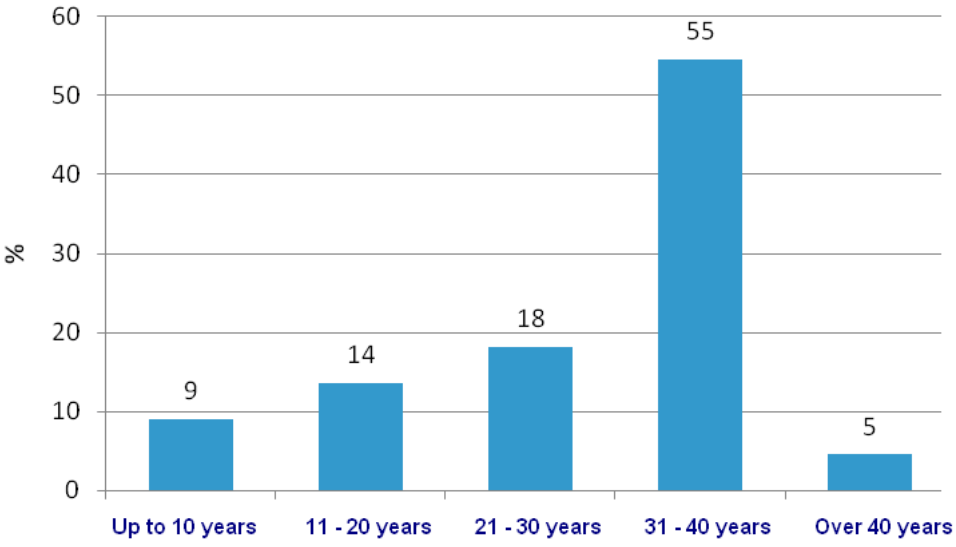
For the analysis of results of importance and applicability of maintainability requirements found in the research *Maintainability Requirements: Experts' Analysis*, it counted on twenty-eight answered interviews, from maintenance performers that operate in different economic sectors (petrochemical, information etc.) and typs of processes (metal-mechanic, oil and others), as well as academics (professors, post graduated etc.) and class-representatives (Federations, Class Associations etc.).

The professionals' profile, considered in the research as maintenance experts, are on average of fifty years old, 52% of those professionals being post graduated, 41% graduated and 7% with technical school formation. Their time in command of organizations maintenance is on the average of eighteen years, given that 47,8% of them have been in command for more than twenty years, and, of these, 57% have been in command for more

than thirty years; Graphic 1 groups the experts according to their time in command of maintenance, by percentiles. In relation to time of activity in maintenance, the ratio is twenty-seven years, given that 59% of them have more than thirty years of activity in maintenance, as shown in Graphic 2 groups expressed by percentiles.



Graphic 1 – Time in command of the Maintenance Experts



Graphic 2 – Time of activity of the Maintenance Experts

VALUES ATTRIBUTED BY THE EXPERTS TO THE MAINTAINABILITY REQUIREMENTS

As to Importance as to Applicability variables, the Levene's test revealed the existence of significant differences amongst the groups variances. To repair this issue, the natural logarithm transformation was applied on data.

The Importance of the Requirement for Maintainability in the Performance of Maintenance Services

The evaluation of the existence of significant differences amongst the investigated requirements emerged from an One-Way ANOVA, the requirements being considered as groups, while the repetitions were each answerer's evaluations. The supposition of homoscedasticity was confirmed through Levene's test and presented significant results to the level of 1% of significance in both observed variables. This pattern violation was repaired through the logarithmical transformation in the two cases.

Considering the Importance variable, the ANOVA's result revealed the existence of significant differences amongst the requirements to the level of 5% ($p<0.001$). The *Post Hoc LSD* was employed as a complement of the Variance Analysis and the results are exposed on Table 1.

Table 1 - Results of ANOVA's[1] complement for Importance variable (LSD)

Requirements	Averages	Test Results*
Reform of Old Equipment	6.78	A
No Random and Structural Dependence Between Components	7.14	AB
Use of Minimal Maintenance Specializations	7.20	AB
Minimal Use of Adjustments	7.26	ABC
Tradition Breakage	7.42	ABCD
Dislocations Decrease	7.69	BCDE
Consideration of Climatic and Environmental Restrictions	7.72	BCDEF
Fail-Proof Methods	7.87	CDEFG
PCM Related to the Lifetime	7.88	CDEFG
Pathology Detection Near the Occurrence Method	7.98	DEFGH
Durability of Systems and Equipment under Environment Conditions	8.09	EFGHI
Generation of Detritus and Fluids	8.11	EFGHI
Repairing Action Impact	8.20	EFGHIJ
Adequacy, Interchangeability, and Compatibility between Devices and Equipments	8.20	EFGHIJ
Experiences Registry	8.21	EFGHIJ
Simple and Safe Access	8.28	EFGHIJK
Common, Classical and General Domain Techniques	8.33	EFGHIJK
Facility of Assembly and Disassembly	8.35	FGHIJKL
Proactiveness in Performance	8.36	FGHIJKL
Logistics	8.47	GHIJKLM
Task Complexity Reduction	8.50	GHIJKLMN
Autonomy and Agility for the Performance	8.55	HIJKLMN
Performance Facilities	8.55	HIJKLMN
Technical Quality of Materials and Tools	8.55	HIJKLMN
Benchmark in Practice	8.59	HIJKLMNO
Criticism Rules for Planning	8.59	HIJKLMNO
Systems for Detection of Abnormal Conditions or Errors	8.65	IJKLMNOP
Clear, Concise, and Easy Comprehension Information through all Activities	8.66	IJKLMNOP
Planning of Replacement Pieces and Modules	8.67	IJKLMNOP
Basic Necessities Attendance	8.67	IJKLMNOP
Users Signalizing and Protection Devices	8.71	IJKLMNOP
Technically Adequate Work Environment	8.80	JKLMNOPQ

Standardization and Revision of Procedures	8.80	JKLMNOPQ
Determining of Error Points	8.81	JKLMNOPQ
Services and Inspections Report	8.84	JKLMNOPQ
Determining of Fragile Points	8.84	JKLMNOPQ
Area Restriction/ Isolation	8.85	JKLMNOPQ
Empowerment and Capability Policy	8.87	KLMNOPQR
Applied Reliability	8.89	KLMNOPQR
Materials and Execution Specifications	8.91	KLMNOPQR
Maintenance Policy	9.01	LMNOPQR
Maintenance Supervision	9.03	MNOPQR
Available and Updated Illustrations and Diagrams	9.07	MNOPQR
Availability of Raw Materials and Extra Pieces	9.13	NOPQR
Proper and Universal Tools	9.15	NOPQR
Decrease of the Occupational Exposure to Risks	9.24	OPQR
Attitude and Responsibility Capacities	9.25	PQR
Previous Work Arrangement	9.41	QR
Pause Management	9.52	R

* Averages followed by equal letter do not differ to the level of 5%.
[1]Variance Analysis using subjects as blocks. FV=Requirements ($F_{48.1233}$=6.669; p<0.001).

The items with higher averages, which represent the highest importance according to the interviewed experts, were: Empowerment and Capability Policy, Applied Reliability, Maintenance Supervision, Available and Updated Illustrations and Diagrams, Availability of Raw Material and Extra Pieces, Proper and Universal Tools, Decrease of the Occupational Exposure to Risks, Attitude and Responsibility Capacities, Previous Arrangement of Work, and Pause Management (items followed by letter R). Noticeably, it does not include requirements about environment, directly associated to the location of performance of services. On the other hand, the requirements Tradition Breakage, Minimal Use of Adjustments, Use of Minimal Maintenance Specializations, No Random and Structural Dependence between Components and Reform of Old Equipment were the ones with lowest averages, and thus, considered less important by the answerers. Such condition demonstrates that these requirements are neglected, even all related to the technical section and referential to the performance of maintenance tasks.

Applicability of the Maintainability Requirement in the Performance of Maintenance Services

Considering the Applicability variable, the ANOVA's result revealed the existence of significant differences amongst the requirements to the level of 5% (p<0.001). The *Post Hoc LSD* was employed as a complement for the Variance Analysis and the results are exposed on Table 2.

Table 2 - Results of ANOVA's[1] complement for Applicability variable (LSD)

Requirements	Averages	Test Results*
No Random and Structural Dependence between Components	5.98	A
Reform of Old Equipment	6.17	AB
Use of Minimal Maintenance Specializations	6.19	AB
Minimal Use of Adjustments	6.22	ABC
Tradition Breakage	6.40	ABCD
Pathology Detection Near the Occurrence Method	6.67	ABCDE
Fail-Proof Methods	6.77	BCDEF
Adequacy, Interchangeability and Compatibility between Devices and Equipments	6.94	CDEFG
Consideration of Climatic and Environmental Restrictions	7.00	DEFGH
Dislocations Decrease	7.17	EFGHI
PCM Related to the Lifetime	7.24	EFGHI
Applied Reliability	7.26	EFGHIJ
Generation of Detritus and Fluids	7.26	EFGHIJ
Systems for Detection of Abnormal Conditions or Errors	7.36	EFGHIJK
Facility of Assembly and Disassembly	7.48	FGHIJKL
Autonomy and Agility for the Performance	7.48	FGHIJKL
Performance Facilities	7.52	GHIJKLM
Available and Updated Illustrations and Diagrams	7.54	GHIJKLM
Task Complexity Reduction	7.54	GHIJKLM
Durability of Systems and Equipment under Environment Conditions	7.59	GHIJKLM
Logistics	7.61	GHIJKLM
Determining of Fragile Points	7.66	GHIJKLM
Technically Adequate Work Environment	7.68	HIJKLM
Availability of Raw Materials and Extra Pieces	7.73	HIJKLMN
Experiences Registry	7.76	IJKLMNO
Criticism Rules for Planning	7.77	IJKLMNO
Decrease of Occupational Exposure to Risks	7.80	IJKLMNOP
Area Restriction/ Isolation	7.81	IJKLMNOPQ
Determining of Error Points	7.83	IJKLMNOPQ
Proactiveness in Performance	7.83	IJKLMNOPQ
Benchmark in Practice	7.83	IJKLMNOPQ
Standardization and Revision of Procedures	7.85	IJKLMNOPQ
Planning of Replacement Pieces and Modules	7.89	IJKLMNOPQ
Basic Necessities Attendance	7.98	JKLMNOPQ
Maintenance Policy	7.99	JKLMNOPQ
Technical Quality of Materials and Tools	8.00	KLMNOPQ
Repairing Action Impact	8.02	KLMNOPQR
Users Signalizing and Protection Devices	8.02	KLMNOPQR
Simple and Safe Access	8.09	KLMNOPQRS
Informações Claras, Concisas e de Fácil Compreensão entre Todas as Atividades	8.09	KLMNOPQRS
Materials and Execution Specifications	8.09	KLMNOPQRS
Common, Classical and General Domain Techniques	8.13	LMNOPQRS
Empowerment and Capability Policy	8.22	MNOPQRS
Previous Arrangement of Work	8.43	NOPQRS
Proper and Universal Tools	8.49	OPQRS
Services and Inspections Report	8.52	PQRS
Attitude and Responsibility Capacities	8.54	QRS
Pause Management	8.74	RS
Maintenance Supervision	8.78	S

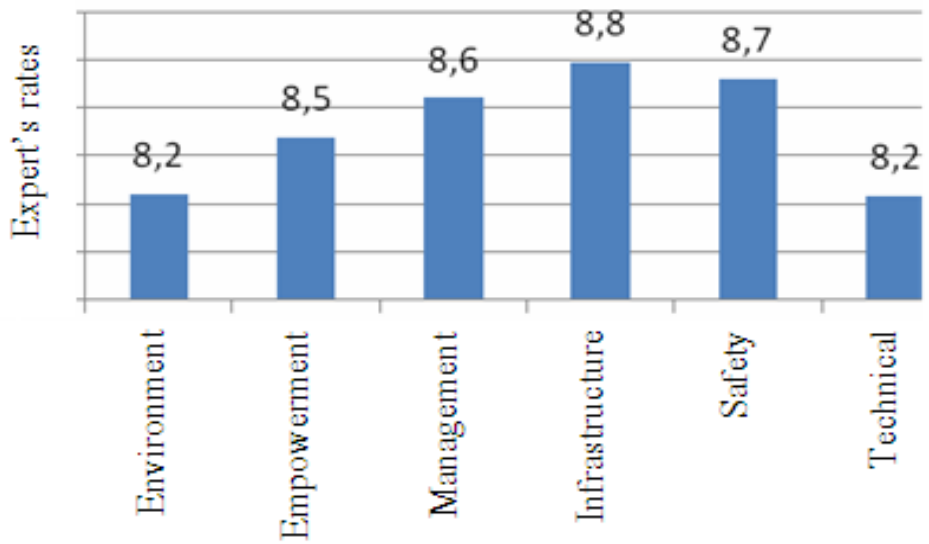
* Averages followed by equal letters do not differ to the level of 5%.

1. Variance Analysis using subjects as blocks. FV=Requirements ($F_{48.1235}$=6.336; p<0.001).

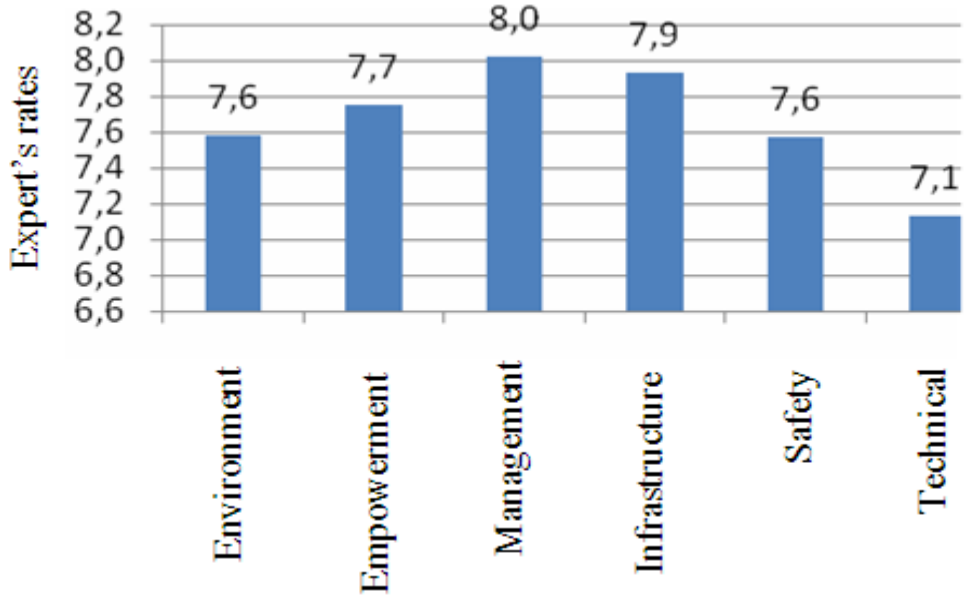
The items with highest applicability according to the interviewed experts, primarily considered by the answerers, were: Simple and Safe Access; Clear, Concise, and Easy Comprehension Information through all Activities; Specifications of Materials and Execution; Common, Classical and General Domain Techniques; Empowerment and Capability Policy; Previous Arrangement of Work; Proper and Universal Tools; Services and Inspection Report; Attitude and Responsibility Capacities; Pause Management; and Maintenance Supervision (items followed by letter S). Among these requirements, there is not a representative of safety section. Yet, it is visible that Empowerment Policy, Maintenance Supervision, Availability of Raw Material, Proper and Universal Tools, Attitude and Responsibility Capacities, Previous Arrangement of Work, and Pause Management were also considered the most important.

In contrast, the requirements with lowest applicability, according to the answerers, were: No Random and Structural Dependence between Components; Reform of Old Equipment; Use of Minimal Maintenance Specializations; Tradition Breakage; and Pathology Detection Near the Occurrence Method. The largest part of the requisites which were considered of lowest applicability to the interviewed experts is related to the technical section. In this case, there is also an intersection between the items stated as being of lowest applicability and lowest importance. They are: Tradition Breakage; Use of Minimal Maintenance Specialization; No Random and Structural Dependence between Components; and Reform of Old Equipment.

Concerning to the qualification of the requirements' class-sections, the sections environment and technical were the lowest-rated on importance, even though considering that there is not a remarkable difference amongst sections on this issue. The better-rated sections by the experts upon importance were infrastructure, management, and safety, Graphic 3. On the subject of applicability, the lowest-rated sections by the experts were technical, safety, and environment; the best-rated were management and infrastructure, Graphic 4.



Graphic 3 – Experts' Averages for the Requirements' Importance by Section



Graphic 4 – Experts' Averages for the Requirements' Applicability by Section

EXPERT'S CONSIDERATIONS ABOUT MAINTAINABILITY REQUIREMENTS IN THE PERFORMANCE OF MAINTENANCE SERVICES

On the experts' considerations about maintainability requirements, were registered punctual reflections upon the requirements, as well as the generic discussion over the theme and the problem of establishing maintainability requirements for the performance of maintenance services in an organization.

What remained evident from the considerations is that, in the latter years, with the seek for environmental preservation and safety improvement in the companies, maintainability has been underprivileged, for what should be compensated by the increase of productivity resulting of training, standardization, and the use of materials and equipment of better reliability and facility of maintenance. This condition led to the maintainability improvement through the maintenance planning, which encloses training necessity, use of tools, materials and the required support to the performance of services.

It was assumed that there is concern about the development of capabilities and what was identified as the processes' governance, achieved through the empowerments and experiments that ease the detection of problems, risks and processes; there is concern about what causes a better intervention and decision. Reflections upon the impact of mistakes in the processes, of embedded costs in the maintenance and equipment, are also mentioned. The results highlight the necessity of investigating the existing technical relations, as with suppliers as with costumers, internal and external, upon the matter of environments in which the equipments and installations operate or are installed. Still on the considerations, it could be identified the necessity of existence of an adjustment engineering, which would be responsible for the continuous search for the conditions' analysis, in the permitted adjustments in the programs an interventions. Another remarkable factor is the use of historic registry and guidelines learned during the process of maintenance management.

As a punctual remark, the necessity of clarifying more emphatically one of the most important factors to the maintainability improvement, which is the participation of the maintenance experts in the original concept/project teams, as well as in the construction/assembly of the new enterprises, systems and components, which would avoid some current difficulties and deficiencies that could aggrieve the future maintainability (deficient layouts, absence of performance facilities, errors in machinery installation – affixation, alignment, etc.).

It was discovered that most of the hardest maintenance problems have, as primary causes, issues related to project, assembly and operation; therefore, solved these causes, many maintenance problems could be avoided. In relation to the operation, it is important the interaction between operation and maintenance, in which the operation team may accomplish some equipment evaluation tasks to assure the operational integrity and continuity. The elimination of the causing agent by the analysis of the error basic cause would diminish the level intervention in the diagram and the application of maintenance engineering with the

purposes of modernization, adequacy and substitution of equipment, promoting the diagram's efficiency.

In a wider investigation, there is the assumption that the experts understand that maintainability is straightly connected to proactiveness and consciousness of well-doing. The professional of this area is supposed to exercise all inspection techniques, as the sensitive as the predictive ones, because the anticipated knowledge of any anomaly will bring, as a consequence, the availability of a larger period to the intervention itself, and certainly this intervention will be a narrower dimensions one, in which the professional will be able to perform an accurate maintenance plenty of time.

In general, the managers recognized their responsibility for the availability of all the necessary resources so the team may develop their activities. Nevertheless, there is the consideration that necessary resources are different from desired resources. Desired resources are those the professional believes necessary to perform his/her functions, and that, at times, are more that what he/she really needs; necessary resources are the actually demanded ones to maintaining the equipments and processes available and reliable. The last, by manager's responsibility, must be in accordance with the necessities and available resources in the company.

DISCUSSION

For the purposed end of the study, the reflection to be produced is focused in the comprehension of the importance and applicability degrees rated by the maintenance experts to the presented maintainability requirements. The detection of a higher or lower attributed value represents how the expert, in his knowledge, admits more or less the necessity of observing the requirement and the possibility of achieving it in an organization.

In relation to the averages attributed by the experts to the requirements, about importance and applicability, they have fluctuated from 6.8 to 9.5 and from 6.0 and 8.8, respectively. This value dispersion in relation to the forty-nine requirements suggests the necessity of a comprehension which is very sensitive to the perceptions and peculiarities attached to the different functions and segments in which these experts accomplish their activities, due to the small difference between the attributed values. The evaluation from a wide scope of specialties enriches the analyses and enhances a more generic evaluation upon the experts' understanding.

For the analysis of results, it is assumed that the requirements that obtained the lowest evaluation are those that he experts consider less as adequate, in contrast with the identification of these in literature, which does not categorize them by importance or capacity of implementation, but as necessary items to the reach of a better maintainability. This way, the lowest evaluated requirements would be those to be developed in the organizations, without disregarding those which degrees of importance and capacity of use are reckoned and applied.

By examining the statistic information about importance and applicability of maintainability requirements, resulting from the developed research, it is possible to presume that there are groups without significant difference between their values. These, in relation to the remainder groups, may be identified as those requirements which are less or more appreciated by the experts. Hence, these are the ones which should be preferentially verified on the observation of the performance of maintenance services.

By evaluating the distribution of the attributed rates by the experts in regard of importance and applicability of the requirements in the research, it was concluded, in a classification of highest and lowest rated values, that there are occurrences of higher and lower values concentration in certain sections (Table 3).

Table 3 – Extreme Appreciation by Sections

Extreme rates by section	**Applicability – highest rates**	**Applicability – lowest rates**	**Importance – highest rates**	**Importance – lowest rates**	**Applicability and Importance – highest rates simultaneously**	**Applicability and Importance – lowest rates simultaneously**
43%	22%	8%	20%	10%	12%	8%
Environment = 20% Empowerment = 75% Management = 43% Infrastruture = 40% Safety = 20% Technical = 50%	Management > 50%	Technical = 75%	Infrastruture and Management = 50%	Technical = 80%	Management = 50%	Technical = 75%

It is clear that there are extreme appreciation rates for near a half of the requirements, given that the sections in which a higher concentration happens are the empowerment and technical ones. Remarkably, the lowest-rated requirements on importance and applicability belong mostly to the technical section, responsible for guiding the specifications, performance, and control conformity.

On the importance, the group that expresses the condition of the requirements which may be developed without significant statistic difference, by the applied method, is identified by order on Table 4. The initial statement is that the major part belongs to the technical section, what immediately impacts on the conception of performance of maintenance services.

Another way, still on the importance, the requirements which were best considered by the experts are present in the technical and management sections, in decreasing order on Figure 2.

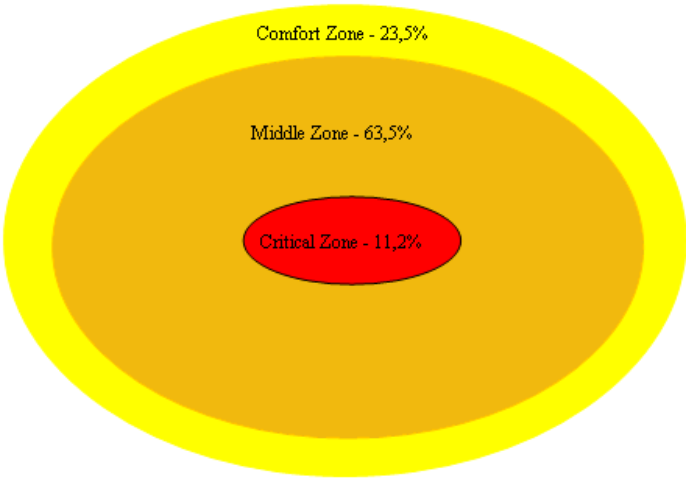
On the topic of applicability, Table 4 shows the group of maintainability requirements with lowest evaluation and that may be developed. It is noticed that this group is almost entirely the same of requirements identified as less important and that belongs mainly to the technical section. The requirements with highest applicability evaluation appointed by the experts are mostly from the technical and management sections, very similar to the group of the best considered about importance, described in decreasing order.

Requirements which may be developed		**Best considered requirements**	
Importance	**Applicability**	**Importance**	**Applicability**
Reform of Old Equipment	No random and structural dependence between components	Pause Management	Maintenance Supervision
No random and structural dependence between components	Reform of Old Equipment	Previous Arrangement of Work	Pause Management
Use of Minimal Maintenance Specializations	Use of Minimal Maintenance Specializations	Attitude and Responsibility Capacities	Attitude and Responsibility Capacities
Minimal Use of Adjustment	Minimal Use of Adjustment	Decrease of Occupational Exposure to Risks	Services and Inspection Report
Tradition Breakage	Tradition Breakage	Proper and Universal Tools	Proper and Universal Tools
	Pathology Detection Near the Occurrence Method	Availability of Raw Material and Extra Pieces	Previous Arrangement of Work
		Available Illustrations and Diagrams	Empowerment and Capability Policy
		Maintenance Supervision	Common, Classical, and Public Domain Techniques
		Maintenance Policy	Materials and Execution Specifications
		Materials and Execution Specifications	Clear, Concise, and Easy Comprehension Information through all Activities
		Applied Reliability	Simple and Safe Access
		Empowerment and Capability Policy	

Figure 2 - Identification of requirements to be developed

These similarities reinforce the considerations made by the experts, that maintainability's improvement is related to the maintenance planning, to the empowerment and use of the necessary tools, materials and support for the performance of services.

There is, as a consequence of the analysis and similarities, middle groups between the best and worst evaluated by the experts, which represent 65% of the full roll of requirements. These indicators can be identified as middle-importance and acceptance issues by maintenance, though presenting significant statistic difference. Such a region can be classified as having moderate importance and applicability. Graphic 5 expresses, by emergency logic, the position of the requirements with lowest evaluation that may be developed in a denominated critic condition, which represents 11.2% of the totality of related maintainability requirements.



Graphic 5 – Requirements by Emergency Zones

The position of the requirements by emergency zones suggests that there is the necessity of a special approach for those which lay in the critical zone, which contains 11.2% of the totality of maintainability requirement connected to the performance of maintenance services. For those, due to their lower consideration by the experts on importance and applicability, it would be convenient to dedicate a special approach – Figure 3.

Requirement	Importance	Applicability
Pathology Detection Near the Occurrence Method	-	X
No Random and Structural Dependence between Components	X	X
Tradition Breakage	X	X
Reform of Old Equipment	X	X
Use of Minimal Maintenance Specializations	X	X
Minimal Use of Adjustments	X	X

Figure 3 – Critical Requirements

Noticeably, in confronting the evaluations pointed by the experts on importance and applicability, Tables 3 and 4, on the average the evaluations attributed to applicability are 10% lower than the attributed to importance. It can be inferred that such difference evidences the difficulties related by the experts in relation to the availability of resources by the

companies, to the non-interaction between maintenance and operation and to the organizational inflictions on the effectiveness of their processes.

In the middle zones of the average values attributed by the experts on importance and applicability, the recurrent requirements in both evaluations are not those with higher or lower frequency of incidence in literature (Figure 4).

Adequate Work Environment	Performance Facilities
Basic Necessities Attendance	Detritus' Management
Autonomy and Agility	Clear, Concise Information
Benchmark in Practice	Logistics
Applied Reliability	Standardization and Revision of Procedures
Determining of Error Points	Planning of Pieces and Modules
Determining of Fragile Points	Experiences Registry
Determining of Error Points	Emergency rules
Durability	Área Restriction/ Isolation
Materials Specifications	System for Detection of Conditions

Figure 4 – Recurrent requirements in the middle zones of attributed values on importance and applicability

It comes to be relevant, as well, to contrast the maintainability requirements by incidence in the researched literature with the researchers' evaluations. It can be verified that 50% of the six requirements considered as critical coincide on the matter of lowest incidence of references in literature (Figure 5). The remainder critical requirements are grouped amongst half of the requirements with lowest incidence of references in literature. Nonetheless, the best appreciated requirements by the maintenance experts, recurrent both in performance and applicability, do not coincide with the highest incidence of references in literature.

Lowest Frequency of Incidence		**Highest Frequency of Incidence**	
Requirements Recurrent for Applicability and Performance in the Research	**Literature**	**Requirements Recurrent for Applicability and Performance in the Research**	**Literature**
Reform of Old Equipment	Reform of Old Equipment	Proper and Universal Tools	Empowerment and Capability Policy
Use of Minimal Maintenance Specializations	No Random and Structural Dependence between Components	Attitude and Responsibility Capacities	Applied Reliability
Minimal Use of Adjustment	Minimal Use of Adjustment	Previous Arrangement of Work	Standardization and Revision of Procedures
	Área Restriction/ Issolation	Pause Management	Performance Facilities

Figure 5 – Requirements' incidence in Literature

Regarding the less frequent requirements in relation to the authors, it can be noticed that these authors also do not mention such requirements as recurrent issues, like Cascone (1992) to Reform of Old Equipment and Minimal Use of Adjustments and ISO16949, NBR15100, and Cascone (1992) to Use of Minimal Maintenance Specializations. On the

topic of Considerations of the Expert about Maintainability Requirements in the Performance of Maintenance Services, however, the analysis of the average rates attributed to the requirements by the experts revealed some inconsistencies, such as:

a) Even considering the seek for the environment's preservation and the increment of safety in the companies, the experts did not attributed the best evaluations to environment and safety requirements on importance, and on applicability they only indicated the decrease of occupational exposure as a safety matter. In relation to literature, it also does not reference environment and safety requirements as the more frequently approached, corresponding to 8.8% the mentioned requirements which refer to environment, remarked by Cascone (1992), Duek (2005), Graziano (2006), ISO14000, Muniz (2005), NBR14280, NBR5674, NR17, Nunes & Valladares (2004), Oliveira (2007), OSHAS18001, Pinto & Nascif (1998), SA8000, Silva (2007), Vieira (2007); on safety, the percentile is 5.9%, referenced by Almeida (2001), Hobbs (2006), NBR14280, NR17, Oliveira (2007), OSHAS18001, Reys (1995), Salermo (2005), Sellitto (2007), Silva et al. (2005) and Vieira (2007);

b) Empowerment and proactiveness are mentioned as important for maintainability in the performance of maintenance services, which is evident from the 75% displayed in the column Extreme rates by section of Table 3, not included significantly amongst the lowest evaluated and critical requirements. On the frequency of approach in literature, the empowerment section holds 13.5% of the totality of referenced requirements, standing for the highest incidence requirement, remarked by BS3811, Dhillon & Liu (2006), Gonçalves & Nagano (2005), ISO16949, Kardec & Zen (2002), Mason (2000), Muniz (2005), NBR15100, Nunes & Valladares (2004), Oliveira (2007), Pinto & Nascif (1998), Reys (1995), SA8000, Salermo (2005), Silva et al. (2005) and Slavutzki (2010);

c) Registry of history and lessons learned through the maintenance management process are mentioned as important. Even so, the requirement Accumulated Experiences Registry does not appear amongst the most important or applicable by the experts, or in the most developed approaches in literature, representing 1.3% of incidence amongst the identified requirements, verified from the norms NBR5674, NBR14280 and SA8000.

Therefore, reflections and hypotheses might be raised in this landscape where the following questions are particularly highlighted:

1. Have the experts realized that, in practice, the requirements with highest incidence in literature are obvious and, for that reason, there is not a relation between the highest evaluations and the frequency of incidence of these requirements in literature?
2. Why does not literature approach proportionally the more and less important issues or those which are necessary to be developed together with the maintenance experts?
3. Why there is not accordance or similarity about the requirements which were adopted by the experts as more or less important in relation to literature?
4. Why the best appreciated requirements by the experts are not so approached in literature?

It is manifest in the discussion an apparent disagreement between what is referenced in literature and the maintenance experts' perception. This possible misalignment between literature and practice may be a consequence of the scarce academic theoretical discussion on maintenance in organizations. The reduced number of magazines, as verified in Qualis/CNPQ System, and the nonexistence of research lines dedicated to maintenance, confirmed in the Superior Education Institutions, may be the alert symptom to the necessity of an increased number of research and elaboration on the subject.

CONCLUSION

The study's goal, to identify a group of maintainability requirements for the performance of maintenance services, was observed. It was figured that the categorized requirements are important guidelines in the aim for improvement and implementation of maintainability requirements in maintenance program and control. Thereby, in relation to the attained research, it was confirmed as a form able to learn, understand and detect the beginning of innovations in the contemporary culture, capable to be sensitive to views and concepts of groups, like a tool for the organization development, innovation and guarantee of quality.

The availability of resources and the definition of maintenance policies are essential for the fulfillment of the maintainability requirements. The discussion on the necessity of conformity conditions to the processes of performance of maintenance services is expected to progress, because, in the lack of it, the relation between elaboration and theory will not approach the practice as the organizations operate it.

Thus, the attempts to align maintenance to the organizational results depend on the investment on the performance of services. They also depend on the conditions of work environment, on the observance of norms and legislation, on safety and comfort conditions for the working crew and, mostly, on an organizational policy focused on the development of the strategic function of maintenance.

The results extracted by the observance of maintainability requirements are correlated to all the management processes of the organization: people, safety, health, materials, resources, means, systems, equipments, and others, suggesting the strategic function that performs the maintenance; in other words, assuring the continuity of the production processes with operation availability and systemic reliability, sustaining the results that guarantee business.

Nevertheless, identifying the maintainability requirements for the performance of maintenance services does not close the case. It must be established a systematic which is capable of evaluating the level of fulfillment of the maintainability requirements, starting from a concept of practice standardization and permanent evaluation of processes of maintenance services. Finally, a systematic which ensures the strategic goals of the organization, plans and controls maintenance regarding health, safety and the legal and normative conditions of ergonomic conformity in the performance of maintenance services.

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