MEASURE ELEMENTS OF MAINTAINABILITY ATTRIBUTE OF PRODUCTS

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Abstract: *This paper discloses a discussion about referential elements in order to establish the measure for product maintainability. During the elaboration of product design it is increasingly necessary the inclusion of a maintainability attribute, which along with the reliability attribute organizes the availability of a product´s function. Maintainability means how easily an item can be maintained or replaced to accomplish the required functions, under specific use conditions, when maintenance is carried out according to determined conditions and through prescribed procedures and means. In order to estimate the maintainability attribute, a system of references which results from an interactive process is essential As such, this work presents a structure for addressing those references in order to estimate maintainability. A model of analysis was developed considering tasks which should be developed by designers to embrace maintainability referentials, multicriterial analysis, and Fuzzy logic in order to define measures of maintainability. The results provided an application for an existing product, specifically anesthesia equipment, which evaluates the maintainability attribute aiming to provide information supply to the redesign of a product.*

Key-words: *maintainability elements structure, maintainability measure, maintainability*

1. INTRODUCTION

Product project elaboration is required to definitely include the maintainability attribute in order to make maintenance activities easier, and then, decrease the intervention time for repair and the life cycle cost (ALVAREZ, 2001).

The product life cycle definition described by Back et al. (2008) and Blanchard et al. (1995), refers to planning, identification of the consumer´s needs, conception, production, operational use, obsolescence and disposal.

For Patton (2005) many products such as home appliances were designed to suffer from repair and maintenance during their life cycle, which lasted for around ten years. Nowadays, most of those products are disposable, with an average life cycle of five years and the project cycle of six months. However, many products are projected to receive maintenance actions, either because of the high reposition cost or their long life time. However, there are the ones that are disposable – for which liability is very important – and the ones that are maintainable – in this case, maintainability is also fundamental. In the second case they are usually bigger, more expensive and more complex equipments.

In order to analyze a product maintainability attribute we need to consider qualitative and quantitative requirements according to Pinto and Xavier (2001).

The maintainability attribute has been drawing the attention of institutions that seek to keep competitive, providing accurate and fast services, with quality for all the members of the chain.

2. MANTAINABILITY

The maintainability concept became more important in the United States in 1954, in the military force, because of the studies of liability developed in the late 40´s. The MIL-STD-470-B (Military Standards) (USA, 1989), MIL-STD-470-A (USA, 1997) and MIL-HDBK-472 (USA, 1984) regulations set the definition of maintainability, according to these regulations, it is a characteristic that must be taken into consideration in the project phase and, afterwards, in the product use, expressing the probability of how the system(s), subsystem(s) or component(s) get recovered within an average repair time, when the maintenance action is performed according to resources and procedures prescribed.

In Brazil, the regulation that defines maintainability is NBR 5462 (ABNT, 1994), according which maintainability is the ability of a product to be maintained or be ready to perform its required functions, under specific use conditions, when maintenance is performed under determined conditions and through the procedures and means prescribed.

Maintainability, according to the definitions presented, influence on the quantity and the need for maintenance, on the average service time, its predictability, availability, operational regularity, cost, efficacy and maintenance quality (PATTON, 2005; BLANCHARD et al., 1995).

For Alvarez (2001) a more adequate and updated definition of maintainability must include project, logistics, man hour preparation, cost, ergonomics, safety and environment characteristics.

Dias (1996) treats maintainability as a function M(t) where (t) is the random variable, related to life cycle, indicating the probability to get the component ready to use again, equipment, technical system in time (t),explicit by the manufacturer. Time (t) indicates the probability to reestablish the necessary conditions to operate in the "as good as new" condition. The time $t_1>t$ is the variable required to determine non-maintainability, that is, the time required beyond predicted. The non-maintainability function can be used also for the case the operation returns to the "not as good as new" condition.

In this context, a question could be asked: what could influence on the maintainability function? When correlating maintainability with maintenance actions we could consider ergonomics and logistics. But velocity in the logistic times of identification of cause is also important, reposition of the failing item, failure cost, the kind of fixation and the assembling sequence. This, among others, will contribute to determine the average time until the repair (MTTR). This time is an important reference to obtain the reposition (or repair) rate which will compose the maintainability calculation.

When the introduction of the maintainability concept is not considered when developing a certain product, the maintenance intervention costs become elevated due to long time and complexity of to perform it. This concept also contributes to decrease the intervening of maintenance on complex products.

Here, some factors that must be taken into account to analyze the maintainability of complex products, according to Alvarez (2001) are listed: structural easily structured, easily assembled and disassembled, man hour facilitation, ergonomic factors, easy to detect and locate failures, easy to manage, availability, availability calculation and logistics.

Yet, the methods and tools that have been used so far to analyze the maintainability attribute are: block flow diagrams, verification lists (check-list), drawing and croquis, tools such as FMEA/FMECA, consult to historical data base. However, those methods and tools use subjective and unquantifiable methods.

For the failure diagnosis of certain products, also specialist systems are frequently used. Alves (2001) analyzes the role of specialist systems in maintenance, treating of issues related to the product´s maintainability. Diagnosis performs a fundamental role in the maintenance activity, and the use of specialist systems provides part of the knowledge of a specialist to the operators of a certain product. Specialist systems are able to decrease some of the maintenance times such as average corrective maintenance time (TMMC) and the preventive maintenance average time (TMMP), besides helping with the logistic support. Those systems also help define the surplus and disseminate technical information.

According to Dias (2006), not only the repairable but also the irreparable items must be treated also by the maintainability attribute. In the repairable items the maintainability attribute is affected by the maintenance policy, time (failure detection, repair, calibration etc.), cost, logistics, average time between failures – MTBF, access to the failure, tools required, labor qualification and ergonomics throughout the life cycle. In the irreparable items, for the maintainability attribute, the aspects related to the fast replacing of the failing item must be pointed out, such as: failure detection, logistics, cost, ergonomics, easy to replace, replacing time. In both cases the requirement for technical expertise, the required tools and the time of repair are equally important elements in the maintainability context.

The application of the maintainability concept that corroborates to this study, like in product project Dias (2002), Oliveira (2007); medical-hospital equipments Carmo et al., 2007a, 2007b, 2007c, Morais and Mulen (2004), Morais (2004); in computational systems Deissenboeck et al. (2007), Antonellis et al. (2007), Kajko-Mattsson et al. (2006), Al-Kilidar et al. (2005), Aggarwal et al. (2002), Franch and Carvallo (2002), García (2000), Muthana, et al., (2000); in hydraulic systems Vinadé (2003), Alves (2001) and in civil maintenance management Vieira (2007).

3. MAINTAINABILITY ELEMENTS STRUCUTRE

For Blanchard et al. (1995), the product´s requirements to measure maintainability must be set in quantitative and qualitative terms, starting at the product´s planning in each phase of the life cycle so they can be evaluated, making the execution of the corrective measures possible. The evaluation must be carried out through a series of prognostics, estimative, measure demonstration analyses, related to the product´s ability to keep maintained.

The product´s requirements, thus, are characterized according to values and goals unfold from the costumers´ requirements. In this study, a structure of the elements to measure the maintainability grounded and based on Blanchard et al. (1995), Matos (1999), Patton (2005) and Melgar (2008), was developed, as shown in the scheme of Figure 1.

The element in this study, according to Figure 1, is defined as the quantity or the information known in order to solve a problem, that is, each part of a whole. Hence the need for the elements to be identified in order to analyze the product's maintainability.

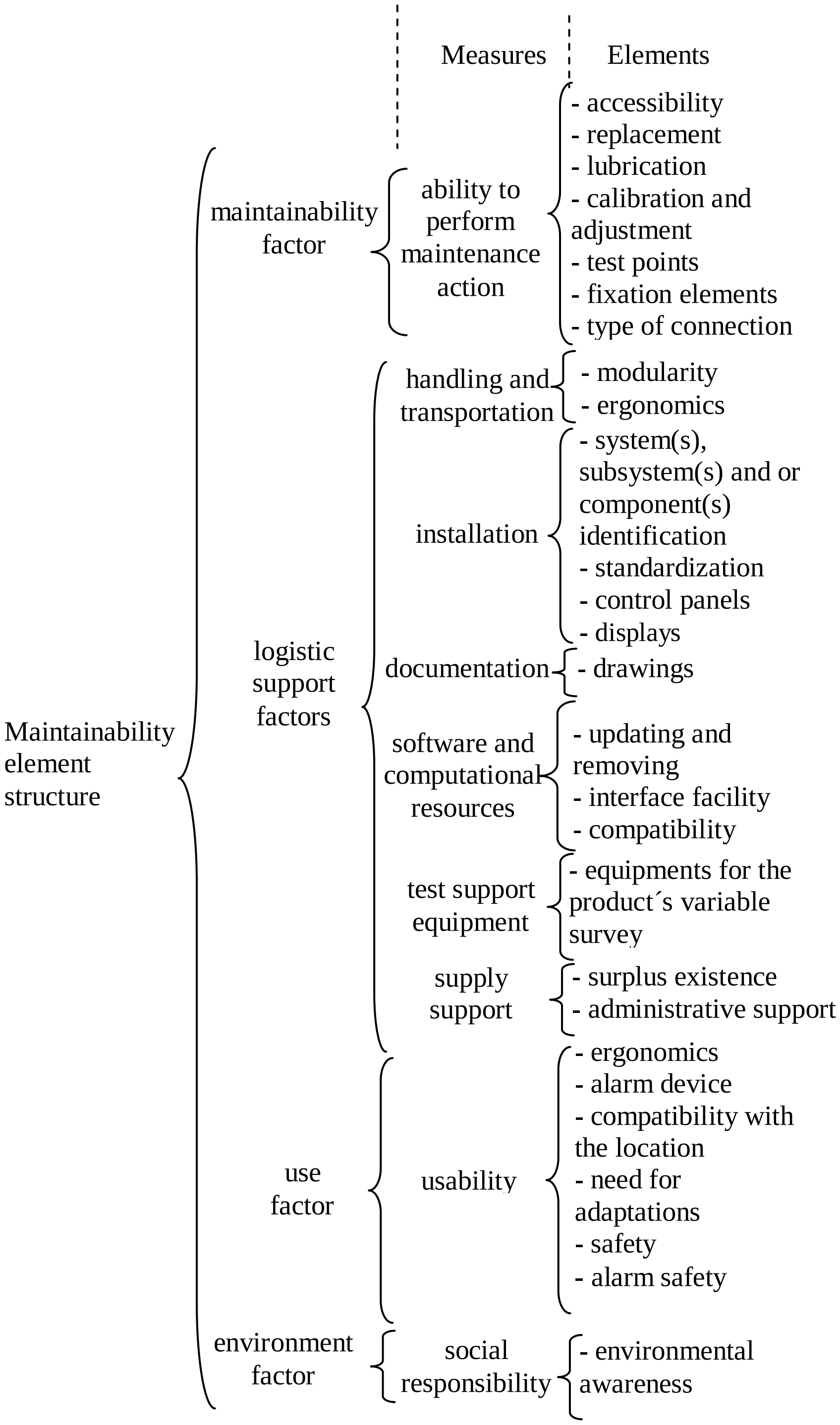


Figure 1. Maintainability element structure (CARMO, 2010)

The maintainability element structure composed by the factors, measures and elements described in the following subsections, can be understood, according to Blanchard et. al. (1995), Wani and Gandhi (1999), Alvarez (2001), Patton (2005), Dias (2006) and Melgar (2008).

3.1 – Maintainability calculation

In the Project for maintainability the designer is visualizing the time and the cost required to get the product back in the “as good as new” condition, when a failure occurs. The parameter that characterizes maintainability is the reposition rate μ(t) according to shown in Figure 2. If the item is failing the chance it will return to normality is defined by μ(t). Thus, as occurred in the liability process, the maintainability calculation processes can be defined according to the distribution of probability that best describes the events and failures that are obtained from the maintenance of a family of products throughout their life cycle.

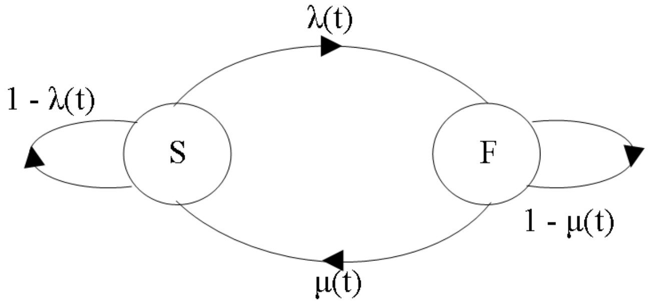


Figure 2. Probability transition between the product´s operational (S) and inoperative (F) states (MATOS, 1999)

In Figure 2 the product´s continuous transition between the operational (S) state and the inoperative (F) state in a certain period of time is illustrated. The product´s situation from the operational status to inoperative status is provided by λ(t), which represents the product´s failure probability in a certain period of time (t). The inoperative status to the operational status is provided by μ(t), which represents the product´s repair probability in time (t)

The complimentary functions, in which the product is found in operation or not being repaired in time (t), as shown in Figure 2, are provided by the terms “1- λ(t)” and “1 - μ(t)”. The term “1- λ(t)” represents the probability of the product to continue in operation or to fail, and the term “1 - μ(t)” represents the probability of the equipment not to be repaired in time “t”. From the point of view in the study of the product´s or equipment´s maintainability, the type Weibull distribution is more general, accurate and practical, which embraces with sufficient accuracy, most of the practical cases due to the shape parameter.

For Dias (1996), from the shape parameter in the type Weibull distribution can be inferred on the project´s variables, production process and use, it is a variable that characterizes the technology level that is aggregated to the system, subsystem or component under analysis.

The type exponential analysis is a particular case of the type Weibull distribution, so it is restrict to some cases, where the failure rate is constant (BILLINTON and ALLAN, 1983).

3.2 Maintainability factor

The maintainability factor is the product´s project characteristic that directs facility, accuracy and the economy to perform maintenance actions, being multidimensional. There are many ways to measure it. The maintainability factor can be measure in terms of a time combination to perform maintenance actions, ability to perform maintenance actions related to the system(s), subsystem(s) and component(s) that are available in the final product. The elements of this measurement make the product´s system(s), subsystem(s) and component(s) maintainability indicators identification easier (BLANCHARD et. al., 1995; PATTON, 2005).

The ability to perform maintenance actions are understood as a set of technical cares fundamental to the product´s regular and permanent functioning, according to Blanchard et. al. (1995), Wani and Gandhi (1999), involving: accessibility, substitution, lubrication, calibration, adjustment, testing points, fixation element and type of connection.

3.3 Logistic support factors

The logistic support is defined as the ability of an organization to provide, under demand, the necessary resources in order to keep an item under the conditions specified and according to the maintenance policy NBR 5462 (ABNT, 1994).

In the logistic support, the support structures needed to transport and storing, that make the product´s information flux easier in order to provide the adequate service to the users and the execution of the maintenance actions are analyzed, according to Blanchard et. al. (1995), Wani and Gandhi (1999), Alvarez (2001), Alonço (2004), Dias (2006) such as: handling and transportation, installation, documentation, software and computational resources, support and test equipment and supply support.

3.4 Use factor

Usability is the product´s fundamental purpose, that is, how the product will perform its functions and its relation to the user. Blanchard et. al. (1995), Alonço (2004) and Patton (2005) point out as elements: ergonomics in the use, alarm device, compatibility to the location, adaptation needs.

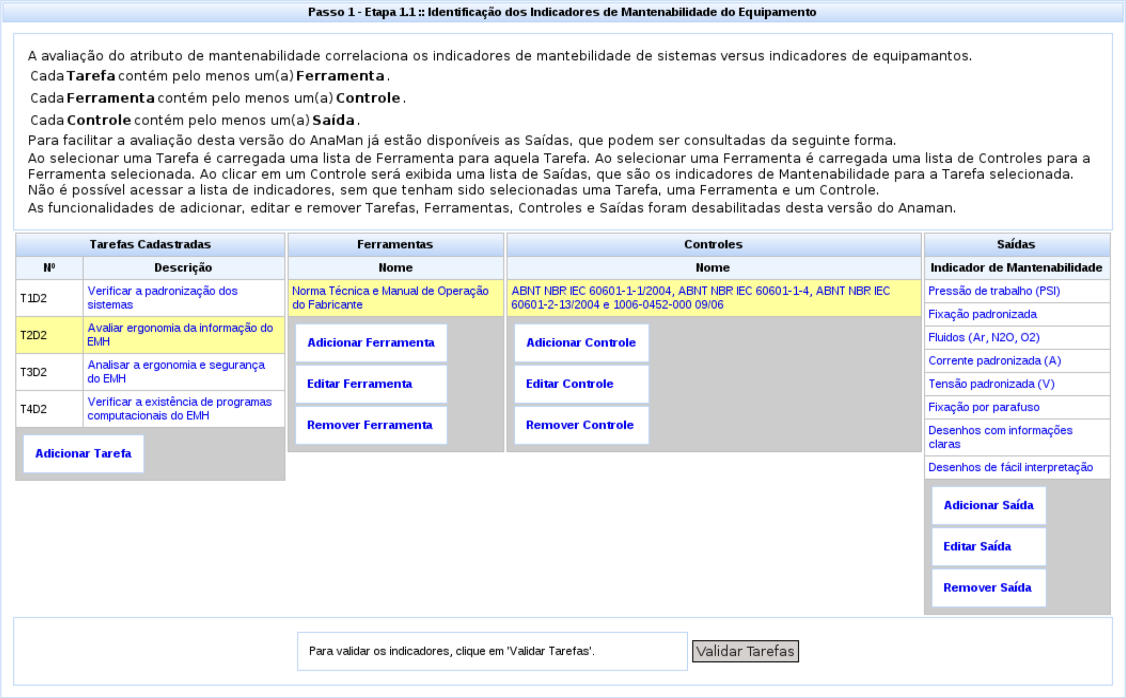
3.5 Environment Factor

Na important role of social responsibility in the environment prevention, with innovations in product development and production that rationalize the use of natural resources, with no aggression to the environment and with procedures to isolate and dispose environmental contaminants. One of the practices of social responsibility is the manufacturer´s contribution in the use of recyclable and/or reusable materials, in its product´s system(s), subsystem(s) or component(s), and in its packages as well (MELGAR, 2008).

In the project´s process initial phases, if those measurements are implanted, the product's competitiveness in the market can be significantly increased, for it decreases the life cycle cost and, consequently, the buying and maintenance cost to the final user.

4. TASK DEFINITION, IDENTIFICATION AND INFLUENCE DEGREE OF THE MAINTAINABILITY INDICATORS

The maintainability indicators are identified by the tasks according to the model presented on Figure 3 and 4, based on the elements on Figure 1. The maintainability indicators identification, Figure 3 and 4, task compound, tool control, exit and value. The task is characterized as an entry in the maintainability indicators identification. The tasks were defined according to the measures presented on Figure 1 helping on the product or equipment maintainability indicator identification. The tools are the technical resources that help on the task execution. The control is performed from the files and information used to survey or to control the use of the tool that executes the task. The exit is the information collected, acquired and processed or transformed by the task into maintainability indicators, which are the parameters that characterize the equipment or product. The value can be represented by a symbol or a letter from the Greek or Latin alphabet.



Passo 1 - Etapa 1.1 :: Identificação dos Indicadores de Mantenabilidade do Equipamento

A avaliação do atributo de mantenabilidade correlaciona os indicadores de mantebilidade de sistemas versus indicadores de equipamantos.
Cada **Tarefa** contém pelo menos um(a) **Ferramenta**.
Cada **Ferramenta** contém pelo menos um(a) **Controle**.
Cada **Controle** contém pelo menos um(a) **Saída**.
Para facilitar a avaliação desta versão do AnaMan já estão disponíveis as Saídas, que podem ser consultadas da seguinte forma.
Ao selecionar uma Tarefa é carregada uma lista de Ferramenta para aquela Tarefa. Ao selecionar uma Ferramenta é carregada uma lista de Controles para a Ferramenta selecionada. Ao clicar em um Controle será exibida uma lista de Saídas, que são os indicadores de Mantenabilidade para a Tarefa selecionada.
Não é possível acessar a lista de indicadores, sem que tenham sido selecionadas uma Tarefa, uma Ferramenta e um Controle.
As funcionalidades de adicionar, editar e remover Tarefas, Ferramentas, Controles e Saídas foram desabilitadas desta versão do Anaman.

Tarefas Cadastradas	
Nº	**Descrição**
T1D2	Verificar a padronização dos sistemas
T2D2	Avaliar ergonomia da informação do EMH
T3D2	Analisar a ergonomia e segurança do EMH
T4D2	Verificar a existência de programas computacionais do EMH

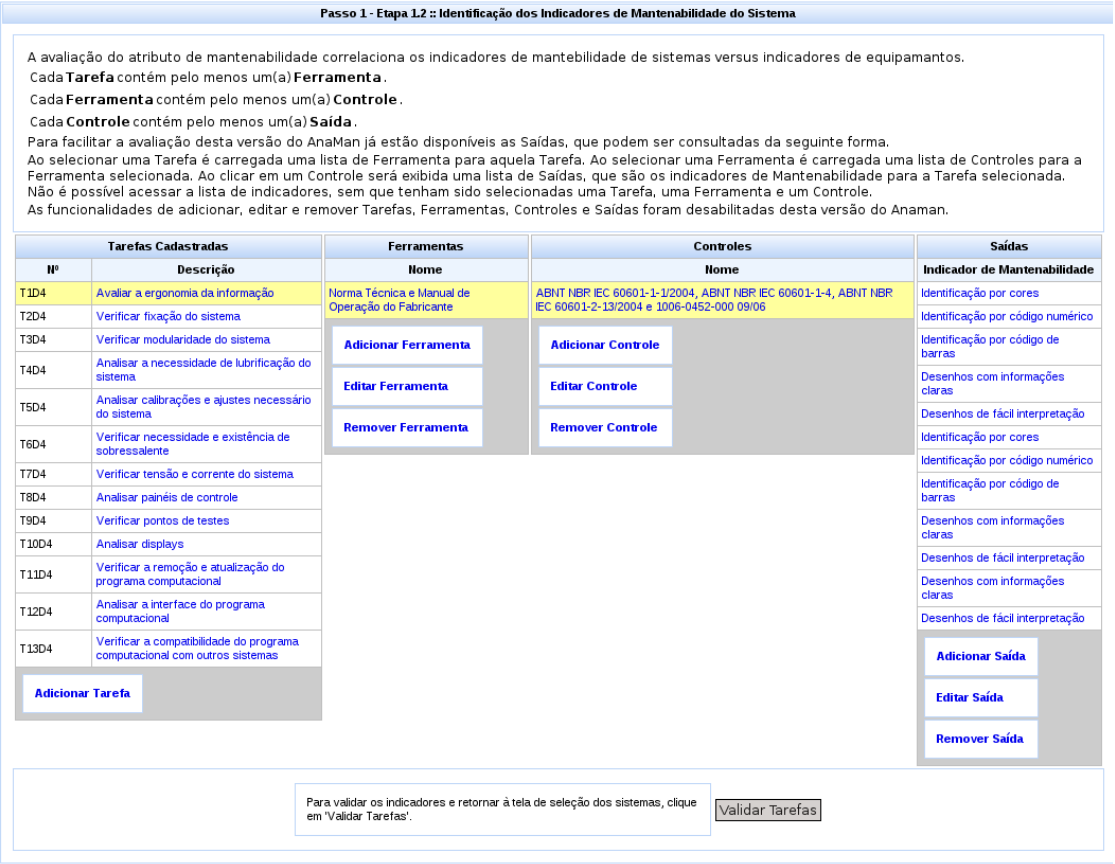
Ferramentas
Nome
Norma Técnica e Manual de Operação do Fabricante

Controles
Nome
ABNT NBR IEC 60601-1-1/2004, ABNT NBR IEC 60601-1-4, ABNT NBR IEC 60601-2-13/2004 e 1006-0452-000 09/06

Saídas
Indicador de Mantenabilidade
Pressão de trabalho (PSI)
Fixação padronizada
Fluidos (Ar, N2O, O2)
Corrente padronizada (A)
Tensão padronizada (V)
Fixação por parafuso
Desenhos com informações claras
Desenhos de fácil interpretação

Para validar os indicadores, clique em 'Validar Tarefas'.

Figure 3. Equipment maintainability indicator identification (CARMO, 2010)



Passo 1 - Etapa 1.2 :: Identificação dos Indicadores de Mantenabilidade do Sistema

A avaliação do atributo de mantenabilidade correlaciona os indicadores de mantebilidade de sistemas versus indicadores de equipamantos.
Cada **Tarefa** contém pelo menos um(a) **Ferramenta**.
Cada **Ferramenta** contém pelo menos um(a) **Controle**.
Cada **Controle** contém pelo menos um(a) **Saída**.
Para facilitar a avaliação desta versão do AnaMan já estão disponíveis as Saídas, que podem ser consultadas da seguinte forma.
Ao selecionar uma Tarefa é carregada uma lista de Ferramenta para aquela Tarefa. Ao selecionar uma Ferramenta é carregada uma lista de Controles para a Ferramenta selecionada. Ao clicar em um Controle será exibida uma lista de Saídas, que são os indicadores de Mantenabilidade para a Tarefa selecionada.
Não é possível acessar a lista de indicadores, sem que tenham sido selecionadas uma Tarefa, uma Ferramenta e um Controle.
As funcionalidades de adicionar, editar e remover Tarefas, Ferramentas, Controles e Saídas foram desabilitadas desta versão do Anaman.

Tarefas Cadastradas	
Nº	**Descrição**
T1D4	Avaliar a ergonomia da informação
T2D4	Verificar fixação do sistema
T3D4	Verificar modularidade do sistema
T4D4	Analisar a necessidade de lubrificação do sistema
T5D4	Analisar calibrações e ajustes necessário do sistema
T6D4	Verificar necessidade e existência de sobressalente
T7D4	Verificar tensão e corrente do sistema
T8D4	Analisar painéis de controle
T9D4	Verificar pontos de testes
T10D4	Analisar displays
T11D4	Verificar a remoção e atualização do programa computacional
T12D4	Analisar a interface do programa computacional
T13D4	Verificar a compatibilidade do programa computacional com outros sistemas

Ferramentas
Nome
Norma Técnica e Manual de Operação do Fabricante

Controles
Nome
ABNT NBR IEC 60601-1-1/2004, ABNT NBR IEC 60601-1-4, ABNT NBR IEC 60601-2-13/2004 e 1006-0452-000 09/06

Saídas
Indicador de Mantenabilidade
Identificação por cores
Identificação por código numérico
Identificação por código de barras
Desenhos com informações claras
Desenhos de fácil interpretação
Identificação por cores
Identificação por código numérico
Identificação por código de barras
Desenhos com informações claras
Desenhos de fácil interpretação
Desenhos com informações claras
Desenhos de fácil interpretação

Para validar os indicadores e retornar à tela de seleção dos sistemas, clique em 'Validar Tarefas'.

Figure 4. Mechanical system maintainability indicator identification (CARMO, 2010)

With the tasks and the use of the tools according to presented in Figure 3 and 4, the product or equipment maintainability indicator identification tasks are executed. With the maintainability indicators identification they result on the entry data for the Influence Degree Matrix. The Influence Degree Matrix is used to define the weight of the product or equipment maintainability indicators and the systems that compose it. This matrix allows us to know the importance of the influence of each one of the indicators on the measure of the product or equipment system(s) maintainability. Knowing the weight of the system(s) maintainability indicator, versus product or equipment maintainability indicators, for example, can establish improvements on the list of the product or equipment project requirements such as: durability, operation and setting facility, noise decrease, maintenance time decrease, use of standard components, avoid the use of special tools for maintenance, present assembling facilities, verify if the surplus are easily acquired, among others.

Taking into consideration that the indicators can directly interfere on the maintainability measure, according shown on Figure 1, it is necessary to analyze its influence degree - G_I. The Influence Degree Matrix was developed based on the AHP method, comparison by parts. The Influence Degree matrix is a tool that aims to provide weigh to the maintainability indicators denominated $IM_{(SISTEMA)}$ that are listed on the lines, and the product or equipment maintainability indicators, denominated $IME_{(EQUIPAMENTO)}$, listed on the columns, according to Figure 5.

Matriz Grau de Influência

Para o preenchimento da Matriz Grau de influência o especialista deve se familiarizar com a página. É possível que a matriz exceda os limites da tela, neste caso surgirão automaticamente barras de rolagem.
O especialista deverá preencher a matriz expressando sua opinião em um valor quantitativo identificado na caixa de seleção em cada célula, de acordo com os valores pré-definidos a seguir:

Grau de Influência entre os Indicadores:

0 - Nenhuma Influência
2,5 - Influência Razoável
5 - Influência Boa
7,5 - Influência Muito Boa
10 - Excelente Influência

Clicando na imagem da interrogação azul em cada célula surge uma tela que identifica o indicador de mantenabilidade do sistema versus o indicador de mantenabilidade do equipamento e os possíveis valores para sua avaliação. Esta tela é fechada clicando na imagem do "X" vermelho no canto superior direito.
Para facilitar o preenchimento da matriz durante a avaliação do AnaMan, existem botões para atribuição de valores nas células para cada matriz.
Ao terminar o preenchimento das matrizes, o especialista deve clicar no botão 'Salvar Peso dos Indicadores' para cada sistema ativado, habilitando os indicadores para o cálculo do 'Cálculo do Índice Geral de Mantenabilidade'.

Indicador(es) do Sistema Mecânico X Indicador(es) de Equipamento

	Pressão de trabalho (PSI)	Fixação padronizada	Fluidos (Ar, N2O, O2)	Corrente padronizada (A)
Identificação por cores	10	7.5	7.5	7.5
Identificação por código numérico	10	10	10	10

Possui dispositivo sonoro	Possui dispositivo visual	Possui dispositivo luminoso	Sistema computacional interativo	GI = Grau de Influência entre os Indicadores	IP = Peso do Indicador
7.5	10	10	7.5	185.00	8.81
7.5	7.5	10	10	190.00	9.05
7.5	7.5	10	10	187.50	8.93

Clicar no botão 'Salvar Peso dos Indicadores' para habilitar o peso dos indicadores.

Salvar Peso dos Indicadores

PASSO 3: Calcular o índice geral de mantenabilidade

Ao terminar o preenchimento das matrizes e salvar os peso dos indicadores, o especialista consegue acessar o resultado clicando no botão 'Cálculo do Índice Geral de Mantenabilidade'. O Cálculo do Índice Geral de Mantenabilidade utiliza a Lógica Fuzzy e retorna resultados em forma numérica e gráfica.

Calcular o Índice Geral de Mantenabilidade

Figure 5. System(s) maintainability indicator Influence degree Matrix - $IM_{(SISTEMA)}$ *versus* maintainability indicators on the product or equipment function $IME_{(EQUIPAMENTO)}$ (CARMO, 2010)

It is important to point out that one or more indicators can be listed on the measures of the Influence Degree Matrix, which might not influence on the final result of a specific system. The influence degree is given by the qualitative evaluation, that is, the specialist´s opinion represented on the Influence Degree Matrix by a quantitative value, $a_{IM_{SISTEMAn}IM_{EQUIPAMENTOm}}$ that represents the system´s influence n on the equipment m. the influence degree valoration scale is given according to represented on Figure 4 (CARMO, 2010).

The product or equipment maintainability indicators, $IME_{(EQUIPAMENTO)}$ are considered as reference indicators to calculate the system maintainability indicators weight - $IM_{(SISTEMA)}$. The sum of each cell of the line on the Influence Degree Matrix has as a result the influence degree– G_I expressed in a numeric value. This relation is provided by the equation (1) (CARMO, 2010).

$$G_{I_{SISTEMAn}} = \sum_{IME_{EQUIPAMENTO}=0}^{IME_{EQUIPAMENTOm}} a_{IM_{SISTEMAn}IM_{EQUIPAMENTOm}} \qquad (1)$$

The weight for each system maintainability indicator is provided by the equation (2).

$$I_{P\,IM_{SISTEMAn}} = \frac{G_{I\,SISTEMAn}}{\sum\limits_{IM_{EQUIPAMENTO}=1}^{IME_{EQUIPAMENTOm}} 1} \qquad (2)$$

The weights of the maintainability indicators can vary from 0 (zero) to 10 (ten). With the weight of each indicator it is possible to observe the influence that this indicator has on the measure of the execution of the maintainability actions, handling and transportation, installation, documentation, computational resources and software, test and support equipments, supply support, usability and the product or equipment social responsibility (CARMO, 2010).

5. MAINTAINABILITY GENERAL INDEX CALCULATION

The entry data for the maintainability General Index are the result if the maintainability indicators, with their respective weights. For the calculation of the maintainability General Index of the anesthesia equipment the Fuzzy Logics Singleton method. The Fuzzy set used in the singleton method in this paper is the trapezoidal one. In the trapezoidal Fuzzy set there is a maximum pertinence interval, indicating that the use must be made in situations where the parameter in analysis has a variation range. And all the sets within this range have the same occurrence possibility.

The $IM_{(SISTEMA)}$ maintainability indicators, with their weights determined by using the Fuzzy Logics is located in the speech universe (X) that varied from (0) zero to (10) tem. Each entry variable is represented by five Fuzzy sets: Bad, Reasonable, Good, Very Good, Excellent, as it is shown in Figure 6.

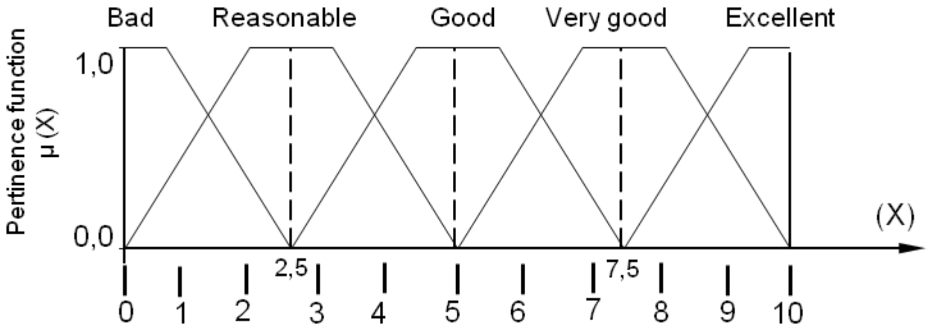


Figure 6. Fuzzy sets graphic representation (CARMO, 2010)

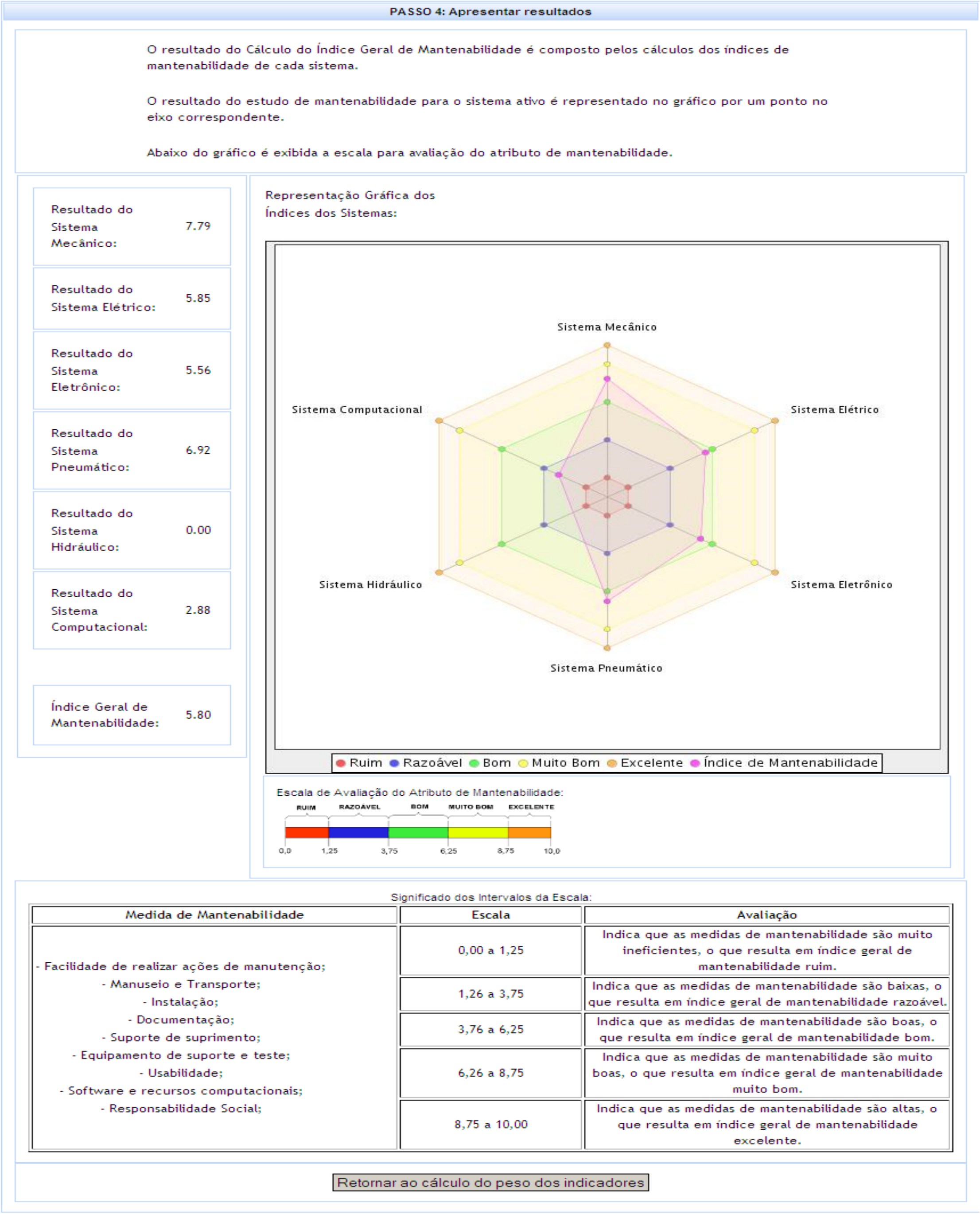
To calculate each system´s maintainability based on the Singleton method, we produce rules that consist of one part that is condition (IF) and another part, conclusion (THEN).

The (IF) part may consist of more than one pre-condition connected to linguistic conjunctions such as (AND). With the Fuzzy sets and the pertinence function established, the Fuzzy rules are then defined.

The Fuzzy sets are defined based on the process that we intend to control or calculate. This process is represented by the knowledge of specialists and empirically adjusted, for it defines the primary terms that compose it.

When the maintainability General Index presents a result that equals zero, it indicates that the anesthesia equipment maintainability is bad. For the maintainability General Index equal to ten, which indicates that maintainability is excellent.

For the intermediate values the measure scales must be consulted, in order to evaluate maintainability. The scale and the meaning of the scale intervals of the measures to evaluate the anesthesia equipment´s maintainability is represented on Figure 7.



PASSO 4: Apresentar resultados

O resultado do Cálculo do Índice Geral de Mantenabilidade é composto pelos cálculos dos índices de mantenabilidade de cada sistema.

O resultado do estudo de mantenabilidade para o sistema ativo é representado no gráfico por um ponto no eixo correspondente.

Abaixo do gráfico é exibida a escala para avaliação do atributo de mantenabilidade.

Resultado do Sistema Mecânico: 7.79

Resultado do Sistema Elétrico: 5.85

Resultado do Sistema Eletrônico: 5.56

Resultado do Sistema Pneumático: 6.92

Resultado do Sistema Hidráulico: 0.00

Resultado do Sistema Computacional: 2.88

Índice Geral de Mantenabilidade: 5.80

Representação Gráfica dos Índices dos Sistemas:

Escala de Avaliação do Atributo de Mantenabilidade:

Significado dos Intervalos da Escala:

Medida de Mantenabilidade	Escala	Avaliação
- Facilidade de realizar ações de manutenção; - Manuseio e Transporte; - Instalação; - Documentação; - Suporte de suprimento; - Equipamento de suporte e teste; - Usabilidade; - Software e recursos computacionais; - Responsabilidade Social;	0,00 a 1,25	Indica que as medidas de mantenabilidade são muito ineficientes, o que resulta em índice geral de mantenabilidade ruim.
	1,26 a 3,75	Indica que as medidas de mantenabilidade são baixas, o que resulta em índice geral de mantenabilidade razoável.
	3,76 a 6,25	Indica que as medidas de mantenabilidade são boas, o que resulta em índice geral de mantenabilidade bom.
	6,26 a 8,75	Indica que as medidas de mantenabilidade são muito boas, o que resulta em índice geral de mantenabilidade muito bom.
	8,75 a 10,00	Indica que as medidas de mantenabilidade são altas, o que resulta em índice geral de mantenabilidade excelente.

Figure 7. Anesthesia equipment analysis result

6. CONCLUSION

It can be concluded that, the maintainability attribute informations made by factors, measures and elements allow getting tasks to identify the maintainability indicators of the product. To give value to the maintainability indicators an Influence Degree Matrix and Fuzzy Logic were developed to calculate the general index of maintainability for the product. The numeric value of the general index of maintainability eases the acquisition of products and also involves several technical, economical and ambiental variables.

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