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Criticality Analysis for optimising OPEX cost lifecycle

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Abstract: Identification and quantification of cost and value of industrial assets is a field in which much terminology is mixed. When we try to analyze the importance of an asset for our business, to discuss about its costs should not be separated from the value provided by the asset. Most of the times, managers only use the term "cost" because it seems to be more objective. Value is more subjective and more difficult to define. However, we must try to use definitions as amortization, inflation, replacement value in order to simplify the concept of "value" to improve our decisions.

In the case of regulated companies, the economic valuation of the facilities is based on a legal normative, so the concept of "cost" may turn to be quite useless. Therefore, it is important to use a methodology that allows us to estimate the value of our assets. We have developed a criticality analysis of our infrastructures in order to assess the relative value of these items for the company. The target is to optimize the operation and maintenance (O&M) strategies at a corporate level. This must have a relevant impact in the OPEX of our company, and may be also an impact in future CAPEX.

This paper discusses the methodology and presents clear examples of how O&M strategy is transformed according to criticality assessments.

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1. INTRODUCTION

In this paper, we try to explain how we have used the criticality analysis for maintenance purposes as a base for different working lines of operation and maintenance. Although the main target of the methodology is to optimize the maintenance strategies (as defined in EN 13306:2010), **the concept of criticality allows us to obtain an indirect value of our facilities.**

The adaptation of the theoretical methodology to make it confluence with the company strategy provides you an analysis of the importance of the equipment. The study of the consequences of a functional loss and the frequency of these failures approach us to the concept of relative value of the asset (Puente et al, 2002; Moss et al., 1999). The most critical items won't be probably the most expensive ones, even won't be the equipment with the maintenance plans most detailed, but they will be the equipment in which we spend more time and efforts to make them work properly. **In this case, and although they are not the most expensive ones, are not the most valuable ones?**

2. THEORETICAL MODEL ADAPTATION

Criticality analysis methodology tries to prioritize the equipment of the facility taking in account two main concepts; the frequency failure of an item, and the severity of the consequence of a hypothetical failure. In this section, we are going to describe shortly the way we have developed the methodology and which have been the key points that have allow us to use it as an indirect measurement of value.

The process follows the next steps:

- Determine frequency levels and the frequency factors
- Determine criteria to assess functional loss severity
- Determine criteria effect levels
- Determine non-admissible functional loss effects
- Determine criteria weights in the functional loss severity
- Determine severity per criteria effect
- Determine criticality limits

The process of the work team for the development of the project has followed the steps defined in the theoretical model most of the times (Crespo Márquez et al., 2016) (based always in a mathematical justification or an agreement based on a generally use of the industry).

Despite of this, when the methodology has been developed, the premise has been that the **results derived from the criticality analysis must be aligned with the priorities of the company**. It implies that methodology must serve to the company target, and not in the opposite way. As a result, we will remark some aspects of the methodology that have been

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adapted slightly with the aim that results show as faithfully as we can, the reality of the facility management

2.1 Determine frequency levels and frequency factors

The target of criticality analysis is to prioritize assets evaluating its relative importance for the company. The criticality concept is defined as the product of the failure frequency of and item multiplies by the possible consequence of a functional loss:

Criticality = Frequency failure * Consequence

(CTR = FF *C)

The first step is to determine the frequency levels and the frequency factors. Frequency levels let us to differentiate the assets by its failure frequency. Frequency factor is the weight that we assign to each level in order to use it for the criticality calculation.

Most extended models define four frequency levels (low, medium, high and very high). Our technicians translated these theoretical levels into real management concepts:

- Possible failures
- Acceptable failures
- Repetitive failures
- Non acceptable failures

In this case, the classification proposed by the theoretical model is near the same that the one used by the technicians.

Before fix the frequency factors, we must assign the limits between the different levels of these criteria. Theoretical methods are usually based in mathematical models (e.g. Pareto) that provide us a statistic distribution of the assets in each level. The use of these models guaranteed that all items are distributed equally in the matrix spectrum in order to maximize the sensitivity of the methodology.

In this case, we have defined some concrete values that showed the real management strategy of the company based on the concept of “frequency failures”. **This is a clear example of adaptation of the methodology in order to show our real management model.** It is known that in this case we will find a higher centralization of assets in a concrete failure frequency (in “possible failure” concept). We preferred to have a distribution of assets that present the reality or our facility. It means that we came from a management style that prioritizes availability to efficiency. It leads to be a little bit over maintained and obviously with a very low failure frequency of our assets.

The frequency factors that define the situation of our items in each level of frequency failure are:

- **Possible failures;** an average value lower than one failure every two years
- **Acceptable failures;** an average value of one failure between two years and one year
- **Repetitive failures;** an average value between one and two failures per year
- **Non acceptable failures;** an average value higher than two failures per year

Table 1. Frequency Levels

Annual Frequency Failure	Classification	Management definition
2≤f	Very High	Non acceptable failures
1≤ f <2	High	Repetitive failures
0,5≤ f <1	Medium	Acceptable failures
< 0,5	Low	Possible failures

Once we have defined each level and the frequency failure that marks the limits, we must assign a failure frequency factor. This value will be the data of each level that allow us to obtain a criticality value.

There are many different ways to assign this value. If we had followed the theoretical methodology, this value would be directly related with the limits of the frequency failure defined for each level. In our case, most of the items are in the lowest level of frequency failure. It is logical assuming, as we have exposed before, that during a lot of years we have focused our management model around the concept of availability. So the main aim was to avoid failures doing quite preventive maintenance. To assign values, we start with a single value (“1”) for the lowest level and we increase it gradually for upper levels.

Table 2. Frequency Factors

Annual Frequency Failure	Classification	Frequency Factors
2≤f	Very High	2
1≤ f <2	High	1,5
0,5≤ f <1	Medium	1,2
< 0,5	Low	1

2.2 Determine criteria to assess functional loss severity

To define criteria to assess functional loss, most of theoretical models propose two main concepts; **criteria related with cost and criteria related with safety.**

In order to assure that methodology is aligned to the company strategy (Crespo Márquez, 2002), we have used the asset management policy of the company as a base for the definition of criteria. This policy is sustained in two main concepts. These concepts are the base of every working line that the company is developing in operation and maintenance. **The first base is “integrity”.** In this concept are included definitions as personal safety, industrial security and environmental care**. The second base is “Efficiency and Improvement”** and involved concepts as availability, quality service and maintenance costs.

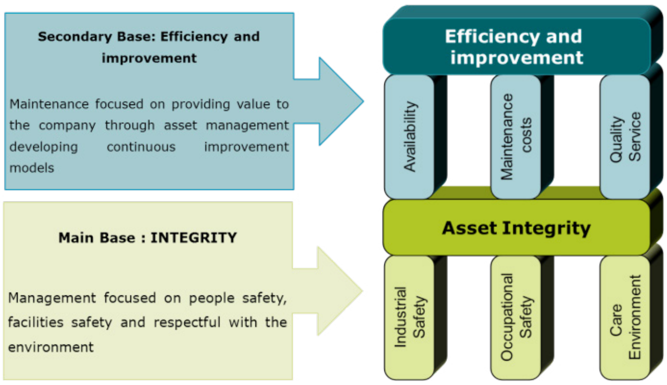

Fig. 1. : Summary of asset management policy

To connect criteria proposed by methodology with the asset management policy of the company, we have defined five analysis criteria based in these two pillars. Two of them are related whit integrity and the other three are related with efficiency. It is important to remark that criteria related with costs don't imply directly "spend money" or "profit lost". These criteria can be related with reputational lost, stakeholder's repercussion or even hypothetical penalties for service loss (the reader can refer to Wireman [1998] to review performance indicators to manage maintenance).

The criteria defined for consequence analysis are:

Safety Criteria:

- Industrial safety: The industrial safety factor assesses the consequences of the functional loss of an element related with:
  - Injuries to internal or third party personnel in the facility, and/or any other person who could be involved in.
  - Damage to industrial assets, products and materials used in production.
- Environmental Care: The environmental factor assesses the environmental consequences of the functional loss of an element, including recovery costs, penalties, compensation, etc.

Cost criteria:

- Quality service: The quality service factor assesses the impact of the functional loss of an element on the gas reception, delivery service conditions, and any other services that Enagas offers to its clients.
- Availability: The availability factor assesses the impact of the functional loss of an element on the installation's nominal capacity.
- Maintenance costs: The maintenance cost factor assesses the impact of the functional loss of an element on the corrective maintenance costs, including costs related with the recovery of the equipment and other equipment that may have been damaged.

2.3 Determine criteria effects levels

The next step is to define the severity levels for each criterion. These levels will measure the gravity of the consequences of a failure. In the same way that we have defined the failure frequency levels, the first step is to assess how many different levels must be defined for each criterion. We have assumed that four levels is an optimum decision to make precise and massive analysis.

For each criterion, we must define the consequences that a functional loss implies in every level**. Each definition must be as simple and explicit as possible.** If we are able to define it very simply, we will limit the possible debates in the workgroup.

The criteria effects levels defined are::

Safety Criteria I; Industrial Safety

- External impact on the facility in a inhabitable or vulnerable area or with fatalities or permanent disabilities; (Catastrophic)
- High impact on the facility extinguished with external resources or external damage to an invulnerable area; or serious injury causing prolonged temporary disability; (Critical)
- High impact on the facility extinguished with internal resources, or minor and reversible injuries to workers; (Moderate)
- Slight impact on the facility extinguished with internal resources; or slight injury that does not affect the work; (No impact/Slight)

Safety Criteria II; Environmental

- External impact on the facility in an inhabitable or vulnerable area (High)
- High impact on the facility mitigated with external resources or external damage in an invulnerable area (Medium)
- Average or low impact on the facility mitigated with internal resources (Low)
- No Impact (No Impact)

Cost Criteria I; Quality Service

- Immediate lack of service (High)
- Loss of critical parameter of gas quality (measure, dust, odorization…) (Medium)
- Loss of non-critical parameters of gas quality (pressure, temperature) (Low)
- No impact (No Impact)

Cost Criteria II; Availability

- Installation shutdown. Total or main operating loss (Very High)
- Loss of nominal capacity of facility (High)
- Loss of redundancy capacity of facility (Medium)
- No impact (Low)

Cost Criteria III; Maintenance Cost

- Maintenance costs derivate from functional loss upper 30.000€ (Very High)
- Maintenance costs derivate from functional loss between 5.000€ and 30.000€ (High)
- Maintenance costs derivate from functional loss between 600€ and 5.000€ (Medium)
- Maintenance costs derivate from functional loss lower than 600€ (Low)

2.4 Determine non-admissible effect levels

At this point, the process requires the definition of those functional loss effects that will be fixed as “non- admissible” for us. It implies to decide in what factor we apply this concept. This characteristic allocates the valued item into the maximum punctuation in consequence (100 in our case) independently of the rest of the assessment.

Looking back at our asset management policy, we apply this “non-admissible” condition just in the factors that are related with safety criteria and with the main base: **integrity**. We define as non-admissible consequence, the maximum level of severity in industrial safety and environmental criteria.

So we assumed that are not admissible for us the next consequences:

- **Industrial safety:** External impact on the facility in a inhabitable or vulnerable area or with fatalities or permanent disabilities
- **Environmental:** External impact on the facility in an inhabitable or vulnerable area

2.5 Criteria weights in the functional loss severity

Other key point for the effectiveness of the methodology is a coherent definition of the weights for assessing a functional loss. Criticality analysis is a semi-quantitative method, so the way we turn consequences into marks will be determinant for the results of the analysis.

It is know that there is an important subjective component in the definitions used for the assessment. But with the bases of the policy and the common sense, is easier to assess the importance of a consequence for the company.

We can describe some premises as example:

- The policy is divided in two main bases, so is logical to distribute equitably the weigh among each of those two pillars; 50% for safety criteria (related with main base of integrity) and 50% for cost criteria (related with efficiency and improvement base)
- In safety criteria, we decided to assign more weight to personal safety criteria face to environmental, because personal safety implies human consequences.
- In criteria related with cost, it is decided to assign more weight when consequences could have more structural impact, otherwise it could be a long term consequence (reputational impact, stakeholders impact) face to other criteria that could have a more pure economical consequence in short term (as maintenance costs itself).

At the end we get a table as follows::

Table 3. Criteria weigh

Main Base Criteria		Secondary Base Criteria		
Industrial Safety	Environ mental	Quality Service	Availability	Maintenance Costs
35%	15%	25%	20%	5%
50%		50%		

2.6 Determine severity per criteria effect

The last point to get our assessment table is to fix the severity per criteria effect. As we have done with every criterion, the aim is to assign numeric value for each severity level in order to get a final mark that let us to calculate the criticality level.

There is no specific method to assign this value, but there are some recommendations, as try to assess the consequences of a possible functional loss in an economical way. After getting these values, you can compare them and fix a more logical distribution of weighs. If two consecutive severity levels have approximately double consequences costs, is logical to assume that we can fix a double weigh for the severity value.

Including every assumption that the workgroup has imagined, the result is the next table:

Table 4. Severity per safety criteria

Safety Criteria			
Industrial Safety		**Environmental**	
Catastrophic	100	High	100
Critical	35	Medium	15
Moderate	20	Low	5
Slight	0	No Impact	0

Table 5. Severity per cost criteria

Cost Criteria					
Quality Service		**Availability**		**Maintenance Costs**	
High	25	Very High	20	Very High	5
Medium	15	High	10	High	4
Low	5	Medium	5	Medium	3
No Impact	0	Low	0	Low	1

2.7 Determine criticality limits

The last step is to calculate the criticality and to obtain the graphical display on criticality matrix.

Multiplying frequency failure factor (remember that it is the value we have assign to each level and not the value of frequency failure itself) plus consequence assessment, we obtain a non-dimensional value that represent the criticality level. Following the theoretical models, we have defined three criticality levels. The limits fixed among the different levels are:

- Limit of low-medium criticality: 50 units
- Limit of medium-high criticality: 90 units

With the three values of the equation, we can picture the item into the matrix criticality. The matrix used for the development of the methodology has as dimensions 4*10 (rows by columns). The value of frequency failure is fixed in Y axis. The value of consequence failure is fixed in X axis. This value is obtained as the result of the equation IS+E+QS+A+MC. The assessment of the severity of each criterion must be turned into the weights assignment for each level. In the graphical model, the number of items that are classified in a concrete cell of the matrix is indicated into the cell.

Criticality matrix used for the example let us to distribute the equipment among three areas:

- Non critical area (blank zone)
- Semi-critical area (soft grey zone)
- Critical area (dark grey zone)

Table 6. Criticality Matrix

FF										
2										
1,5			2			3				1
1,2		2								1
1	57	35	20	15	3	1	5	1	9	12
C	**0-10**	**10-20**	**20-30**	**30-40**	**40-50**	**50-60**	**60-70**	**70-80**	**80-90**	**90-100**

3. VALUE OF CRITICALITY

After an assessment of all items of a facility we get the matrix criticality shown in the figure. In this case, we have analysed more than one hundred and fifty items. The difficulty of the assessment is to think about the possible consequence of a functional loss of a concrete item in every criterion. Workgroup must assign the mark of the severity criteria if the possible consequences agree with the definition of this severity criteria level.

One of the key points in the methodology is that we don't care about the prize of the item. Even we don't care about the replacement costs of the item. These are concepts that are not considered into criticality concept. At this point, is shocking to discover that these criteria are not directly related with the function of the item.

The strength of the methodology is that we have obtained quite an objective assessment of the value of the equipment from the company, starting out from a subjective analysis of possible failure consequences.

The criticality matrix is not a target itself. We have used the methodology as a tool for optimising cost opex lifecycle. **The main point for us is to consider this methodology into a general continuous improvement model**. In this line, the Maintenance Management Model proposed by Ingeman (referred) suggests different maintenance engineering methodologies to develop in function of the relative position of the equipment into the matrix. In other words, the Model suggests different methodologies in function of the relative value of the equipment for the company.

For example, for that equipment with a high value of criticality (high consequences and high failure frequency) a failure root cost analysis (FRCA) is proposed. This methodology probably won't be able to decrease our maintenance costs or optimise our maintenance plan, but we will be able to limit unscheduled stops in critical systems. As a result, we will avoid problems with our clients or the availability of the facility. **As the reader can deduce, this assessment is indirectly done in the criteria definition.**

For non-critical equipment, the methodology suggests you a Risk-Cost Optimization (RCO). We have also adapted this methodology in order to review all maintenance plans of non-critical equipment. In a first phase we have focused the efforts in lighten frequency of preventive maintenance. As a consequence, we hope to have an important decrease of our maintenance budget. But the most important point is that we hope to obtain a deeper knowledge of our failure mode equipment. Coming from an intensive preventive maintenance plan, most of the times we avoid the failure, which is probable the most comfortable point, but not the most efficient one. If we have an analysis that let us run to failure or at least reduce the preventive maintenance to these items that are non-critical for the company, **we were able to manage the facility from a safe situation into an efficient one.**

4. CONCLUSIONS

To limit the concept of value to cost terms is to limit the capability of the asset management. Depends on the nature and the specific sector of the company, many other factors must be taken in account.

Criticality analysis allows allocating with a simple methodology your items assigning them a relative value in function of the strategy and target of the company.

It is a very powerful tool and a solid starting point for an **optimising policy of OPEX in the lifecycle.**

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