

ANALYSIS OF METRICS IN THE PRODUCT DEVELOPMENT PROCESS OF THE AEROSPACE INDUSTRY

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ABSTRACT. This paper explores the needs and definitions of metrics in the product development process. The relevance of the subject is easily justified by the ever increasing complexity of the products, and the investments required for its development as well as the need for shortening time-to-market. The objective of this work is to search metrics in the product development process of the aerospace industry. The Brazilian Aerospace Industry has been chosen as case study and reference. The paper reviews the main metrics available in the literature followed by an experimental investigation about the current metrics adopted by the Brazilian Aerospace Industry. This research has yielded a list of eighty-three metrics which were grouped into three main sets: Definitions, Development and Production. These sets were defined based upon the focus of the metrics associate with the functional investigated area. It has also been found that some areas were lacking metrics in spite of having some measuring procedure in place. Based upon these findings, the work supports the development of a method for selecting and defining metrics which are aligned with the strategic goals of the corporation.

Keywords: Metrics; Product Development Process; Performance measurements; Monitoring; Control.

1. Introduction

The market goes by transformations that form a new dynamic context for the organizations and especially for the aerospace industry. Its products have to compete in price and quality with the foreign companies.

The products have a limited useful life and they need to be improved, developed and innovated if the company wants to stay competitive [Barnett and Clark, 1998].

The pressures due the competition have been persuading the organizations to introduce its products in the market faster, cheaper and with better quality [Barnett and Clark, 1998]. This can be achieved by the companies with superior product development process as they take advantage of the opportunities in a more efficient way.

The competitiveness of the product is measured as results of evaluations done by the customer, through several approaches as reliability, after-sales technical attendance, functionalities, cost of the cycle-life, communality of products and financing conditions. The product development process and mainly, the practice of its activities in an integrated way, has great impact on the competitiveness of the product and consequently on the own company.

Little attention has been given by the researchers to the process of implementation of specific strategies of product development and the measure of its acting.

According to Drucker (1996), to manage is to reach goals, that is to say, to obtain results in a predefined period. Therefore, it is important to establish acting measures that allow to evaluate and to subsidize relative decisions to the product development process.

In this scenario, the organization needs to monitor the product development process.

This is particularly true for the aerospace industry, where the dynamism of transformation of the international scenery forces the assimilation and the continuous development of new technologies and products.

In the last years the transformations occurred under several aspects in a definitive and irrevocable way, among others:

- ▲ Growth of the complexity of the products;
- ▲ Significant growth of the investments in the product development;
- ▲ Risk Partnerships: partners are assuming considerable part of the product development;
- ▲ Reduction of the deadline proposed;
- ▲ Need of ever increasing amount of man-hour during the development.

Considering the increase of product complexity, the growth of the necessary investments for its development, the reduction of time-to-market and the growth of the number of partners, the evaluation of the product development process should not be just based on the common sense. It is advisable and rather necessary, to establish a set of metrics to evaluate the product development process, for identifying and guiding the actions of process monitoring and improvement as well as supporting the decision making activity.

This paper aims at investigating the metrics in the product development process of the aerospace industry; the Brazilian Aerospace Industry has been chosen as case study and reference.

The study is based on understanding the concepts, premises, restrictions and other related considerations about the metrics found in product development process: the reasons of their success or failure and the identification of their general characteristics.

2. Literature review

Since the second half of the 20th century, a great progress has been achieved regarding the application of metrics in traditional processes such as manufacture, accounting, and other “well behaved” processes, because of their deterministic and repetitive characteristics. Conversely, the product development processes, methods and similar techniques had experienced little progress. Historically, performance evaluation of the product development process has been based on traditional financial measurements that is, earnings before interest tax, return on investment or return on profits. While these measures reflect what has happened within the process, they are rarely useful to support durable actions of improvement. The scientific contributions in performance measures increased in the decade of 1990, after the publication of the works of Kaplan (1991).

The traditional system of performance evaluation of the product development process, suggested by the company Booz-Allen & Hamilton (1968), was based on financial resources control and the lead time necessary for accomplishing the product development.

Booz-Allen & Hamilton (1994) mention some inconveniences associated with these performance measurements: they emphasize evaluation of results instead of behaviors; they have a limited perspective: focus on a short period on inside the company and on local optimization instead of global optimization. Furthermore they do not encourage technical and managerial improvements.

Changes in technologies, competition and environment (internal and external) are demanding changes in what is measured, how it is measured and how the measurements are used.

Many authors recognize the difficulties in measuring performance in project activities and development. Such difficulties are due to its creative, multidisciplinary and complex nature, as well as the frequent long duration and great sensitivity of the project about lead-times, difficulties in the definition and measurement of the quality of the project, among others.

As pointed out by O'Donnell and Duffy (2001), the decline of financial measurements as the only way of measuring business performance is an unambiguous indication of the tendency of the performance measurements towards less tangible aspects, for example, those related to the activities of intense knowledge in project.

2.1. Importance of the metrics

Measurement, performance evaluation and decision making based in information are important activities of an administration system. A good management practice seeks a multidimensional vision of the strength and success of its organization and develops and uses, consequently, a coherent group of metrics.

Performance measurement plays an important role in the administration of the organizations. Even so, that is as important as to be conscious that performance measurement is not panacea for all the evils that afflict the administration, for as simpler as the organization can be [Silva, 2001].

According to Acosta (2002), the definition of a set of metrics ought to be preceded by the establishment of a goal(s) and a person (or a team) which will guide the enterprise to success. Then, the metrics will help these individuals to make decisions in order to achieve their goal(s).

Measurement and analysis tools make sense only if they allow unchaining actions; otherwise, they represent waste of time, competences and resources. Though, that doesn't mean that the analysis tools are the instruments of the action.

The items that are measured allow to [Macdonald, 2002]:

- ▲ Define how good is your business;
- ▲ Promote information to define and/or extend objectives;
- ▲ Show the progress or probability of success;
- ▲ Identify the root of the barriers;
- ▲ Focus the organization in the necessary improvements;
- ▲ Direct the behavior and actions to reach the objectives;
- ▲ Align work with values;
- ▲ Involve every one.

2.2. Definition of Metrics

A unified terminology for the term “metric” is very important not only for the research community but also for practical purposes.

LaFountain (1999) considers a measure to be a “metric” if it can be impacted by the efforts of the individual or teams with whose incentive the individual or teams are concerned. Measures that cannot be affected by the efforts of the program team are called “covariates”.

In general, the nature of the definitions of metrics that can be found in the literature is strongly influenced by their authors' particular interest on using them

Neely (1995) points out that performance measurement is a theme frequently discussed but rarely defined. Meyer (1994) states that there is a great disagreement in what is performance.

The misunderstanding and miscomprehension of performance and performance measurement can frequently result in ignorant acceptances of private focus, metrics, etc., proposed by managers inside the organization.

Due to the several definitions found in the literature, Acosta (2002) defines four key aspects related to the concept of metric. They are:

- ▲ Establish – implicit or explicitly – the need of having a goal;
- ▲ Metrics as a control instrument;
- ▲ Metric in a decision making context;
- ▲ Metric as an indicator of the human interaction.

2.3. Characteristics and important aspects of metrics

Acosta (2002) insistently mentions that metrics alone are useless; it is the necessary to have a goal which the metrics are confronted against. Besides, he states the main aspects of the metrics that should be looked at:

- ▲ Alignment: build sets of product development process metrics strongly linked to the company strategic goals. "How high-level organizational objectives will be viewed at the process level and how they will effect (i.e. contribute or constrain) upon the specific goals and objectives of development functions and visa versa" [Haffey and Duffy, 2001].
- ▲ Decision Making Process: the metrics are valuable instrument to support the decision making process.

According to Macdonald (2002), the metrics should have the following characteristics:

- ▲ Metrics must be used by leaders to set expectations and drive actions;
- ▲ The organization strategic objectives must be the start point for all performance measurement.
- ▲ Metrics need to be used as a major means of communication both internally and externally and as a means to align everyone's efforts.
- ▲ Performance measures must become key elements in making decisions, setting direction, and correcting course.
- ▲ Metrics have to be both an input and an output of each business process and measurement has to be part of each process.
- ▲ Good metrics need to be:
 - Directional - to confirm that you are on track to reach the goals
 - Quantitative - to show what has been achieved and how much more is to be done
 - Worthwhile - adding more value to the business than they cost to collect and use

Crow (1997) summarizes four criteria for effective metrics:

- ▲ Keep them simple;
- ▲ Keep them to a minimum;
- ▲ Based them on business objectives and the business process - avoid those that cause dysfunctional behavior;
- ▲ Avoid metrics that request significant additional data collection.

As a conclusion of the literature review, it can be affirmed that the theme of metrics in product development is restricted to qualitative aspects such as the qualities that the metrics should have. However, not much is found about the practical operation of the metrics in companies, organization and / or industries. This is actually, the motivation of this research work which is detailed below.

3. Research activities and results

In order to investigating the metrics in the product development process, a series of activities have been accomplished.

Such activities can be divided in two phases: Prospecting and Analysis.

The Prospecting phase involves:

- ▲ Analysis of last experiences with metrics in the case study company;
- ▲ Survey of the needs of measurement and accompaniment of the work, through the knowledge of the reality and practice of the product development in the investigated industry;
- ▲ Identification of the metrics that already exist and are adopted;
- ▲ Understanding of the operation and utility of these metrics.

The Analysis phase involves:

- ▲ Understand the relationship between metrics and what is expected from them;
- ▲ Analyze what should be complemented and what should be created, as far as metrics are concerned.

3.1. Prospecting Phase:

In the prospecting phase it was searched the answer for the following question: What does exist in terms of metrics in the product development process?

A field work has been carried out for identification and registration of the metrics that already existed and were adopted, for questioning the need of measurement instruments for the product development process and for understanding the work and utility of those metrics in the case study industry.

In this field work, the investigation form adopted was to visit several areas and interview key people to collect information.

The investigated areas were the following:

- ▲ Preliminary Design
- ▲ Planning
- ▲ Product Development
- ▲ Marketing
- ▲ Manufacture
- ▲ Organization
- ▲ Quality

The choice of the researched areas was done to obtain, as much as possible, the inclusion of the whole product development process, starting from the product requirements and conception, up to the final product and production.

The selection of the people interviewed was based on the knowledge and/or work they had about metrics in their respective functional areas. The interviews were preceded by previous schedule with the interviewee and they took approximately an hour.

As a mean to accomplish the interview, a questionnaire has been developed with the objective to drive the interview in way to find out the needs for measurement instruments in agreement with the activities and functions of the functional area, as well as to obtain a list of metrics used by each area. How and for whom the metrics are used in terms of acquisition of data and visibilities of the acquired data were also answers sought by the interview.

The questionnaire used in the interviews was composed by the following:

- ▲ What are the activities of the process/team? (what do they do?)
- ▲ Investigation of the metrics:
 - What do you wish to measure? Which points of your activities and tasks need to be measured? (measurement need and accompaniment)
 - What are the metrics used? (lists of metrics utilized or in use)
 - How does each metric work?
 - What is measured?
 - Who makes the measurement? Is there a responsible person?
 - What is the frequency of measurement?
 - How is the data collection done?
 - Result of measurement
 - How are the data processed?
 - How are the results presented?
 - Who are the results presented for?
 - Definition of the metrics
 - How and why was chosen the specific metrics?
 - Reasons of successes and no-success.
- ▲ Which are the study sources, if there is any, utilized to build a set of metrics?
- ▲ How much time was spent in the development and studies of the metrics used?
- ▲ List of involved people: who are, where they are from, how they are involved.

The collected data of the field research, through the interviews with the key people in each area, has resulted a set of 83 (eighty three) metrics, what represents an average of more than 10 (ten) metrics per investigated area.

These metrics show a big and varied range. A short sample is given before a detailed analysis: tests execution, pieces production, reports emission, cost estimate, communality, change request, partners' delivery, men-hour, request for information, request for proposal, non conformities, drawing release, assembly schedule, certification requirements, weight and time.

3.2. Analysis Phase:

In the analysis phase, it has been tried to answer the following question: How does a big and variety range of metrics obtained relate to each other and with the areas they are used?

To do that, the authors have tried to identify the reasons of the use of a specific metric in an area and also the important aspects that a metric has to have. The data collection in the interviews has been followed up with the understanding and analysis of the data, with the objective of discovering the focus of the areas according to the action needs of them.

The area characteristics related with the metrics needed and/or used is presented below.

Preliminary Design:

This area is worried about time controlling and resources commitment, technology and customer satisfaction.

The metrics of this area are not documented or systematized, there is a lack of clarity and they present subjective character; people in this area work for empiricism based on experience and historical data, which are not documented.

This happens because of the creative and abstract character of the work conducted in this area.

As this area works with the beginning of the product development, many of the critical points of the whole development have its origin in this area and they should have controlled right from the beginning.

Planning:

The focus is on controlling what is necessary for the project. Only one person is the responsible for metrics.

The metrics are systematized, including data collection, visibility and frequency. The centralization and responsibility for the metric in one person are important factors to obtain the metrics systematized.

Here, the metrics are not used for team management.

Product Development:

The metrics of this area are in all the phases of the product development, although they are not necessarily the same metrics used during the whole development. In fact, the course of the project is monitored according to the phase that the project is.

In terms of frequency, data collecting (definition of a person that is the responsible) and visibility of the results, the metrics present themselves in a systematized fashion. They are able to signal the product development situation related to the goal. These can be: the goal has not been reached, which demands a contingency plan or the definition of new goal.

Marketing:

The focus of the area is on the customers' requests and on the product requirements.

The area is totally passive about metrics, because the metrics come from another area in graphical form, such as evolution of number of customers' requests in the time.

Manufacture:

The metrics of this area have its focus in the milestone of the process that influences performance of the production line. The metrics are systematic in data collection and visibility, but not so much in frequency. They have a reactive character, since the most active part of the area works towards the definition of the goals and monitoring of what is executed.

The performance critical point of the area is the negotiation and interfaces with other areas for definition the goals.

Organization:

The metrics are defined to assist the strategic objectives of the area.

They are systematic in terms of data collection, definitions of a person responsible for a metric, frequency and visibility. Each metric in this area is treated in a specific way and all of the metrics are shown to every team member.

The critical factor of success is the commitment of every one involved.

Quality:

The metrics of this area are focused on the metrics of the products. They are well systematized in data collection, frequency and visibility, embracing the area where they are extracted from up to the affected areas and beyond.

Such metrics promote corrective rather than preventive actions, even though they can be used for the identification of the product development process critical areas.

Table 1 summarizes the nature of the metrics of each area through their key words.

Table 1. Nature of the metrics of each area.

Area	Metrics characteristics (key words)
Preliminary Design	Customer satisfaction, resources and technology commitment
Planning	Control of the released items, schedule and cost estimate
Product Development	Monitoring in all the phases of the development
Marketing	The customers' request, product requirements
Manufacture	Milestones of the processes that affect the production
Organization	Strategy, alignment, processes and people
Quality	Product, assembly line

According to the nature of the metrics in each area, it is possible to gather them into three main groups, as follows.

Group 1 – Definitions: This group is composed of the areas of Marketing and Preliminary Design: the metrics of this group have focus on the customer and on the initial commitment of the project.

Group 2 – Development: The areas of Planning, Product Development, Organization and Manufacture are component of this group. In the transition from Group 1 to Group 2 there is the area of Preliminary Design. The metrics of this group are concerned about monitoring and controlling several items through the phases that encompasses the whole project development until its end.

Group 3 – Production: This group is constituted of the area of Quality and the transition to Manufacture: the metrics of this group are concerned about the product and its production.

Figure 1 exhibits a pictorial representation of the gathering of the areas into the three groups.

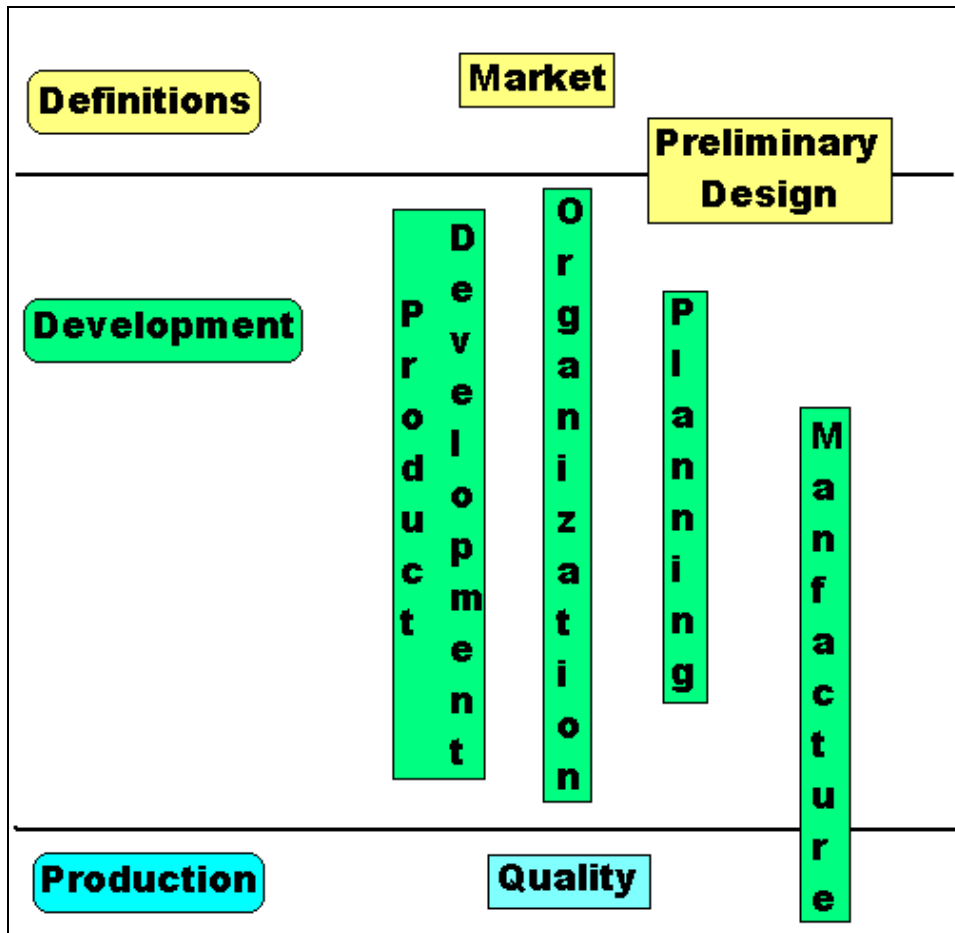


Figure 1 - Grouping the investigated areas according to characteristics of its metrics

By extending the previous analyses, it has been possible to identify some aspects that should be presented in the metrics applied to the product development process.

- The metrics should have an alignment with the strategies and objectives of the company and ultimately, with the very area where the metrics are present and applied. Such characteristic agrees with Crow (1997), Macdonald (2002) and Acosta (2002).
- In conformity with Drucker (1996), MacDonald (2002), LaFountain (1999) and Acosta (2002), the metrics should also be a mechanism for action, promoting actions and/or decision making; that is, if the metrics indicate the need of an action, when this action does take place, it must directly impact back onto the metrics.
- It is important to define who is going to be the user of the metrics and which are his / her needs.

In a company, as people assume different managerial levels, they adopt different types of language: strategic level is concerned in lucrative and financial return; in the operational level, the language of the " things " is used and in the middle term, the tactical level, plays as a bridge between the other two levels, concerning in project "things" that will be lucrative.

Therefore, it is necessary that metrics be molded to the user and his needs. If this is achieved, the metrics will promote the alignment of the whole company; as it is exemplified for some metrics shown in Figure 2.

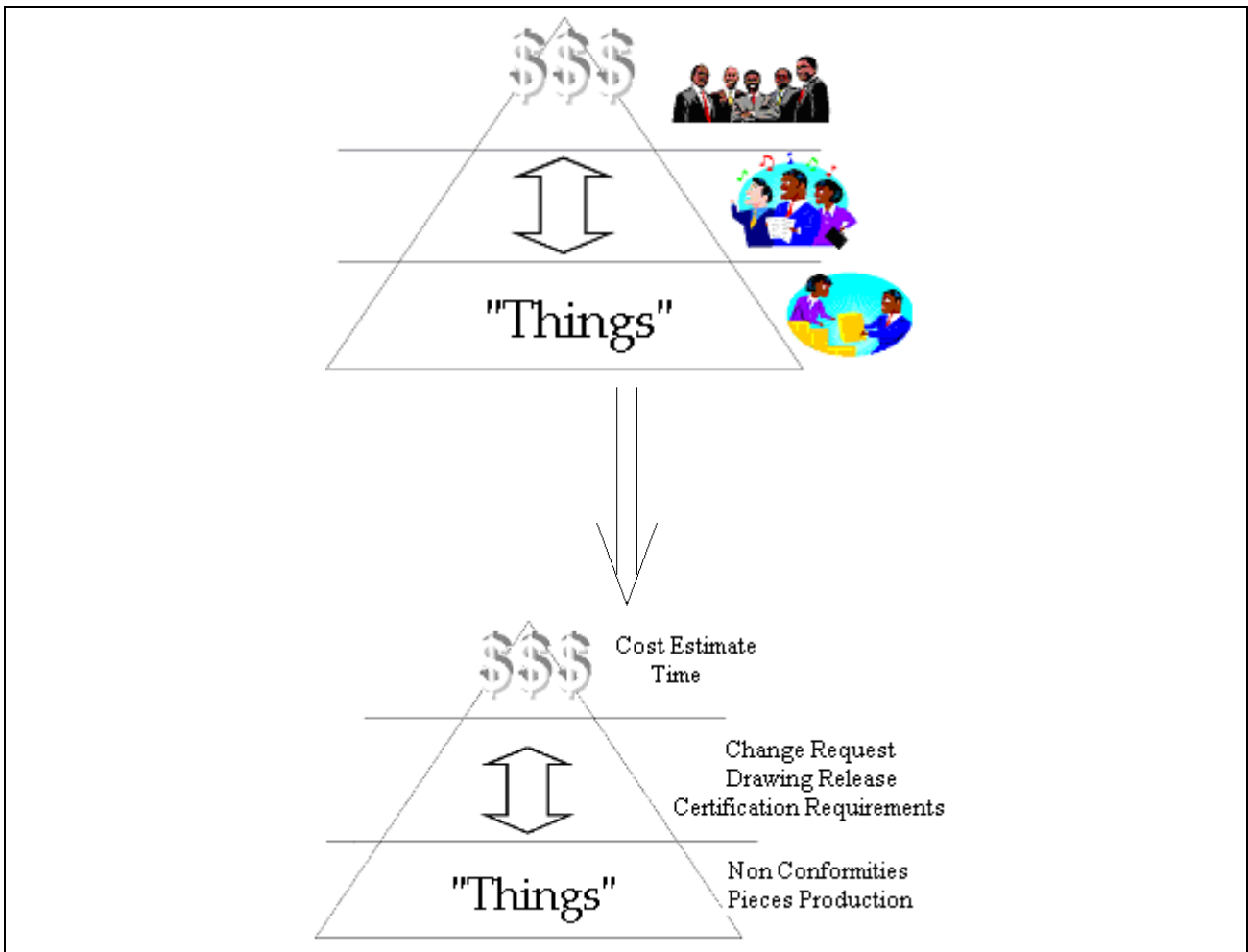


Figure 2 – Corporate Languages and Metrics

The important characteristics which render the metrics to have alignment, action and a more pro-active character come from the answers to the following questions: what is measured; what is the reason of measuring; where and when it is measured, and who is the metric's customer?.

4. Conclusions

The investigation of metrics in the product development process has allowed the understanding of the concepts, premises and other related considerations about metrics; it has facilitated the registration of both the existent metrics and the previous initiatives in the implementation of metrics. Success and failure factors have been identified; as well as the general characteristics that the metrics of the product development process should have.

The field work has yielded a list of eighty three metrics of the investigated areas, associated with the need of each area for monitoring and controlling of the project development right from its beginning up to the final product and its production.

The analysis of the data has resulted in a gathering of the areas investigated in three great groups in agreement with the needs and nature of the metrics in each area.

It has still been identified as general characteristics of the metrics of the product development process, the following:

- ▲ Alignment with the strategies and objectives
- ▲ Unchaining actions and/or decision making
- ▲ Definition of the users and their needs

Finally, the important characteristics which render a metric to have alignment, action and pro-active behavior come from the following questions:

- ▲ What is measured?;
- ▲ What is the reason of measuring?;
- ▲ Where and when it is measured?, and
- ▲ Who is the metric's customer? .

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