DEVELOPMENT OF METHOD FOR MEASUREMENT OF AVAILABILITY IN INDUSTRIAL PLANTS.

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Abstract. *The objective of this paper was to develop a method able to measure the availability of productive units, independent of the production system or amount of used financial resources used. Further, it is suggested that this information be use in the decision making process of competitive strategies. In this article, the deductive hypothetical method was used. For this, we have developed a pilot mode, which was implemented in thirteen productive units, they were monitored for twelve months for tests and improvements. We have implemented the method in all production units since 2006. In the end, the method was able to measure the availability of a productive unit independent of the production system, demonstrating which stages of the process should be measured and generating an indicator to gain competitive and strategic advantages.*

Keywords*: availability, strategy, maintenance and indicator.*

1. INTRODUCTION

Nowadays, the strategic thinking and ability act are important. The necessary activities for production are integrated into the production process, contributing effectively to the success of the company.

According to Pinto et al (2007), this new attitude is the result of the challenges in the new globalized and competitive economy where changes occur at high speed and where the fundamental activity of maintenance, as one of the fundamental activities of the productive process, needs to be a proactive.

In this scenario, improvisation and arrangement are not options. It is necessary to act with competence, creativity, flexibility, speed, culture of change, flexibility, dedication and teamwork to keep the competitiveness required by the market.

Modern business conduct requires a deep change of mentality and attitudes. Management should be based on the vision of future and governed by processes where the full satisfaction of clients is the result of the intrinsic quality of the company's products and services, the total quality of its production processes being the key pillar.

Moreover, the industrialized world is transitioning from an industrial economy to an economy of information. In economy of information, success is determined by the amount of information you know and not by the amount of investments.

Competitive advantage gained by economies of scale maybe counterbalanced by the development and effective use of information. In the economy of information, competition among organizations is based on their abilities to acquire, process, interpret and use information effectively.

The organizations that lead this competition will be the big winners of the future, and those who fail to do so will be beaten easily by competitors. You need process information such as data from internal and external indicators.

Investments in productivity indicators don't produce more advantages than investment in machineries. The value of the indicator depends on its use within the organization.

According to McGee and Prussak (1994), for this it's necessary to specify the strategy, which is allocated between thinking and acting, and provide the definition and simulation activities that are needed to achieve pre-established goals and to satisfy the four criteria below:

- It must be unique, or at least should show how the company will distinguish itself from its competitors.
- It must conduct important target choices (e.g., maintenance management wants to reduce the costs and increase the availability in production).
- It must clearly consider the competitive environment, including customers, suppliers and competitors.
- It must clearly consider all the resources that will be required to implement the strategy, including capital, knowledge and empowerment of individuals.

It's possible to support and place this paper within a successful company, as shown in Fig. 1.

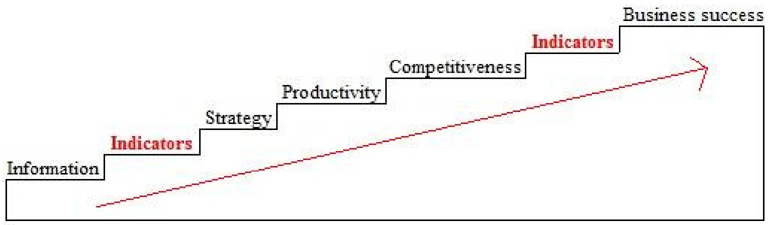

Figure 1. Business success.

The method used in this paper is embedded in business success, as shown in Fig. 1, or, more precisely, in the items and strategy indicators.

Thus, it will deal with the development of a method capable of measuring availability of production units, regardless of the production system or amount of resources used.

Further, it will be suggested how to use with this information and where to place it in the decision making process of competitive strategies.

For this, we have developed a pilot model, which was implemented in thirteen production units. They were monitored for twelve months for tests and improvements. We have implemented the method in all production units since 2006.

2. METHOD

In this paper we used the hypothetical deductive method that according Lakatos and Marconi (2008), follows these steps:

- Identifying the problem the managers of the involved areas talked about, seeking to list data that would be important for the method. Also, we asked the performers what the difficulties for the execution would be and discussed an initial model.
- Constructing a theoretical model, seeking to reduce the variables. The method is modeled according to customer's needs and is based on new and old theories of production. Thus, it compared the model to the facts and phenomena that occur in the field.
- Deducing of particular results. The search for possible adjustments was done, and their impact in the field was deduced and verified.
- Testing of hypotheses with the method in use to do inspections and verification and to monitor progress.
- Establishing the conclusions of the method. We evaluated the need for setting and implementing the adjustments.

In a production unit, the availability factor is essential for defining strategies in maintenance, logistics, production and projects. It is directly related to cost and occupation.

2.1. Application

The proposed method is applicable to production systems continuous or intermittent, which are divided into batch production and order production.

The continuous production system is characterized by a continuous high-volume, standardized product and production of large batches. The production pace is accelerated and operations are performed without interruption or change. In short, products are kept online for a long time without modification. Since the product and production process do not change, the system can be improved continuously.

In practice, these models are represented by continuous assembly lines, chemical production and petroleum refining.

The intermittent production system is characterized by facilities that are flexible enough to handle a wide variety of products and sizes, or where the basic nature of the activity requires major changes in inputs. In this production system it is necessary to implement the availability method in the bottleneck step of process so that will be able to eliminate the deviations contained in that stages of production.

The intermittent batch system is characterized by producing a limited amount of one type of product at a time (called batch production). Each batch is scaled in advance so the company can meet a certain volume of sales expected for a given period of time. Thus, the production batches are produced one after another. This type of batch production is used for a variety of industries: textiles, ceramics, home appliances, electrical materials.

The method of measuring availability should be implemented in the last stage of production, preferably before the order for logistics.

In the intermittent order system, which is characterized by customization, products are specially produced at the order of a customer, such as turbines, tools and dies, special machinery, ships, raw material, etc. Orders generally are not repetitive and quantities may vary from one to hundreds of units. In this type of production, each product usually involves a wide variety of operations and progress, in general, follows no standardized plan or routine. The order or request made will define how the production should be planned and controlled.

In production units that have multiple types or systems, it is necessary to deploy a measuring point for each row and set a weight percentage according to the financial impact for this down time line individually.

The following are examples of how to proceed, according to the production system used.

Example 1 - In continuous production system with a single production line, the bottleneck step of the process must be identified and the control deployed in this step, as shown in Fig. 2.

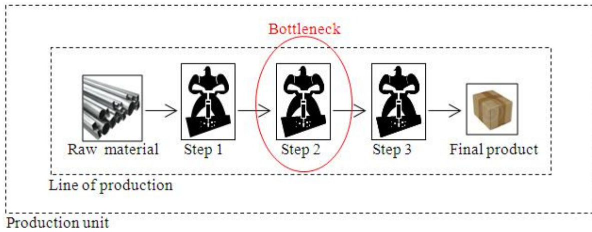

Figure 2. Deployment point in the continuous system with single-line manufacturing.

In this case, the availability of the plant will be the value measured in the bottleneck step.

Example 2 - In continuous production system with multiple production lines, the method must be implemented in bottleneck step of each line, as shown in Fig. 3.

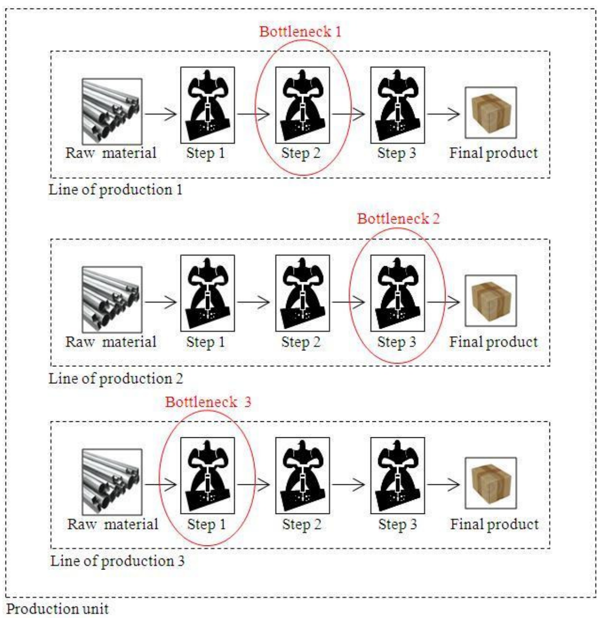

Figure 3. Deployment point in the continuous production system with several production lines.

After finishing the calculations for each of the lines, a weight is defined for each production line in relation to the financial capacity of the products produced on it, and then the weighted average availability of the lines is calculated which represents the availability of the plant.

Example 3 - In the intermittent batch production system, you must be implemented the method of calculating availability in the last production stage, preferably before the order for logistics, as shown in Fig. 4.

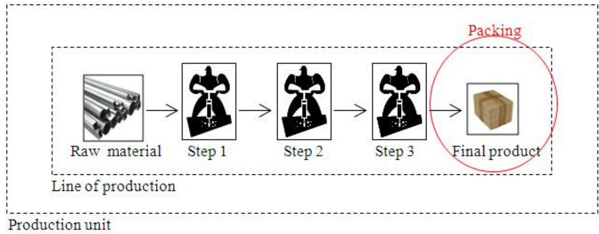

Figure 4. Deployment point in intermittent batch production system with single line.

In this case, the availability of the plant will be the value measured at the packaging stage.
Multiple production lines must also implement the availability method at the packaging stage, as shown in Fig. 5.

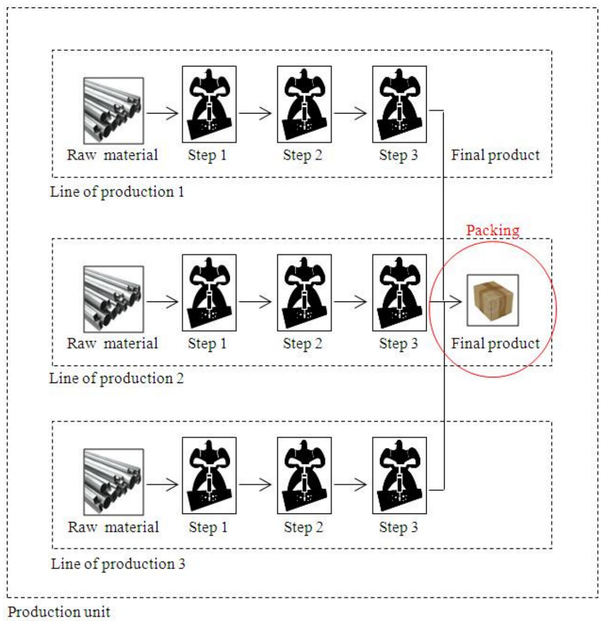

Figure 5. Deployment point in the intermittent batch production system with several lines.

Example 4 – In the intermittent order system, the method of calculating availability must be implemented according to Examples 1 and 2, differing only with careful monitoring of the time that the unit awaits the arrival of the orders - idleness.
In this case, the availability of the plant will be the value measured in the bottleneck step.
The flow of operations must occur as shown in Fig. 6.

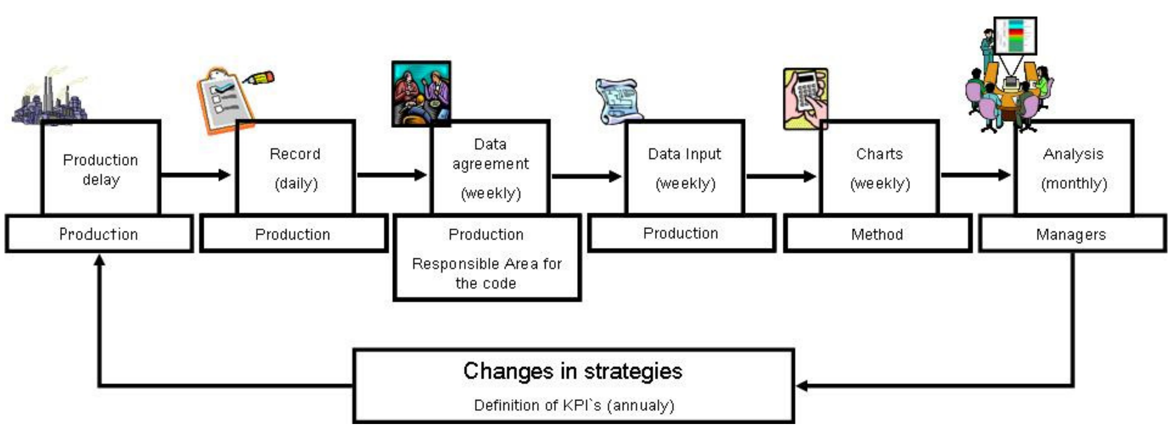

Figure 6. Flow of operations.

2.2. Classification of the down time registration

It is necessary to classify each of the down time that occurs in a production unit.

Based on NBR 5462, this classification should follow these rules:

Down time (Outage): the number of hours unavailable, separated by the reasons that cause the same. This item will be divided into two sub-items: planned and unplanned.

Planned down time: A plant is unavailable if it cannot perform its function (i.e., it cannot produce according to specified requirements). If the circumstances motivating the production loss or delay are caused by planned measures, this will be characterized as planned down time. It is considered planned down time if it has been planned at least thirty days in advance.

The planned down time range is divided into four sub-items: project, production or process, technical and auxiliary reasons.

Project: represents the down time causing planned outages that are the responsibility of the project area, or engineering projects.

Production or process: represents the down time causing planned outages that are the responsibility of the production area (i.e., process engineering, production engineering or managers of the plant).

Technical: represents the down time that causing planned outages that are the responsibility of the technical area (i.e., field engineering, maintenance engineering or technical suppliers).

Auxiliary reasons: it represents the down time that causes outages planned that are the responsibility of the utility areas.

Unplanned down time: A plant is unavailable because of outages, however, this condition is caused by unplanned measures or planned measures less then thirty days in advance.

The unplanned shutdown range is divided into three sub parts: production or process, technical and auxiliary reasons.

Production or process: Represents the down time causing unplanned outages that the responsibility of the production area (i.e., process engineering and production engineering).

Technical: represents the down time causing outages that are the responsibility of the technical area (i.e., field engineering, maintenance engineering or technical suppliers).

Auxiliary reasons: Represents the down time causing unplanned outages that are the responsibility of the utility areas (i.e., a stop in the steam network or the water treatment network).

Theoretical availability: Represents the percentage of availability in the month. It is divided into two sub-items: production and idleness. It is obtained by adding output index to the idleness index.

Production: represents the number of hours available and used to produce.

Idleness: represents the number of hours the plant was available, however it was not productive for to lack of demand.

This classification should be referenced by codes, as shown in Fig. 7 and 8.

Classification	Code	Reason of the down time
Project **planned** down time	11	Execution of projects
Production or process **planned** down time	21	Set-up
	22	Cleanness due the crossed contamination
	23.1	Raw material lack - Logistic
	23.2	Raw material lack - Programming of the production
	23.3	Raw material lack - Purchases
	23.4	Raw material lack - Supply Chain
	24	Cleanness of the system
	25.1	Pack Lack - Logistic
	25.2	Pack Lack - Programming of the production
	25.3	Pack Lack - Purchases
	25.4	Pack Lack - Supply Chain
	26	Reprocessamento de material
	27	Collective vacations
	28	Planned administrative losses
	29	Low performance of the system
Technical **planned** down time	31	Down time Schedule - preventive maintenance
	32	Inspection NR-13
	33	Planned specific maintenance
Auxiliary reasons **planned** down time	41	Lack of energy or utilities

Figure 7. Codes defining the reason for planned down time.

Classification	Code	Reason of the down time
Production or process **unplanned** down time	51	Operational failure
	52	Waiting closing of the previous stage
	53.1	Raw material lack - Logistic
	53.2	Raw material lack - Programming of the production
	53.3	Raw material lack - Purchases
	53.4	Raw material lack - Supply Chain
	54	Cleanness of the system
	55.1	Pack Lack - Logistic
	55.2	Pack Lack - Programming of the production
	55.3	Pack Lack - Purchases
	55.4	Pack Lack - Supply Chain
	56.1	Reprocessamento de material
	56.2	Loss of departure
	57	Waiting for lab analysis
	58	Lack of documentation
	59	Product Transfer
Technical **unplanned** down time	61	Corrective Maintenance
	62	Lack of maintenance personnel - instrumentation or electrical
	63	Lack of maintenance personnel - Mechanical
	64	Lack of maintenance planning
Auxiliary reasons **unplanned** down time	71	Lack of electricity
	72	Lack of water
	73	Lack of compressed air
	74	Lack of nitrogen
	75	Lack of steam
	76	Lack of natural gas
	77	Lack of pallets
Idleness	81	Lack of productive demand

Figure 8. Codes defining the reason for unplanned down time.

The codes shown in Fig. 7 and 8 are important for the precise classification of down time.

2.3. Graphic representation

Through the use of a monthly graphic representations, we were are able to easily identify the reasons that caused downtime, as shown Fig. 9.

The monthly graph is an important point to this paper, because it provided an immediate analysis of the existing scenario.

However, the monthly evolution, as shown in Fig. 12, provides a complete analysis of trends.

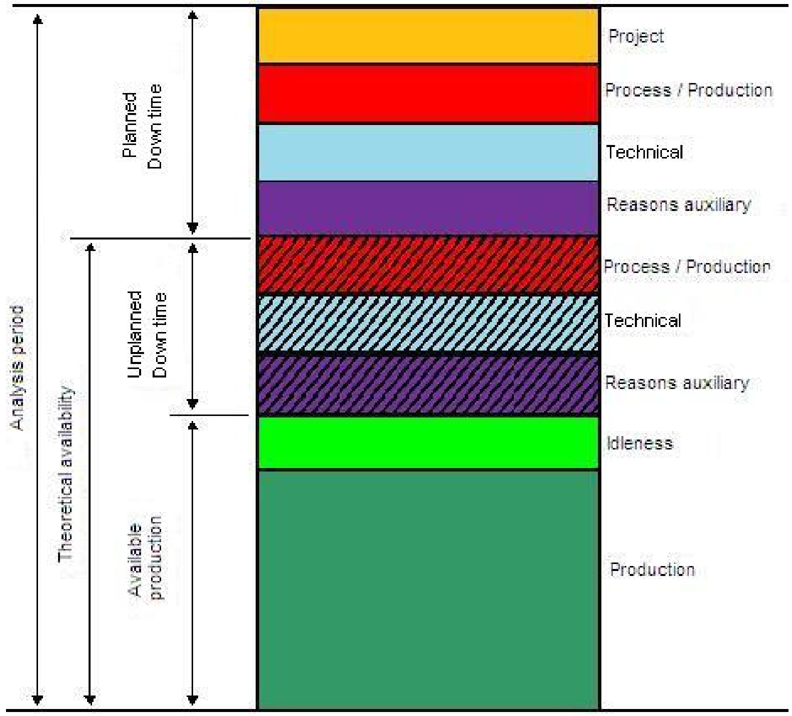

Figure 9. Monthly graph.

3. FORMULATION

The formulata will be divided as shown, in the indicators in the item 2.2, as Fig. 7 and 8 show.

Recently, Lafraia (2008) has said the period under analysis represents the amount of hours in the month, which is obtained by multiplying the number of days worked by 24 hours.

The following is the mathematical representation of the indices:

$$Period\ [hours] = quantity\ of\ days\ in\ a\ month * \ predicted\ time\ to\ produce \tag{1}$$

Down time planned Project:

$$Down\ time\ planned\ project = \sum downtime\ because\ of\ code\ 11 \tag{2}$$

Down time planned production or process:

$$Down\ time\ planned\ production / process = \sum downtime\ because\ of\ codes\ 21\ to\ 29 \tag{3}$$

Down time planned technical:

$$Down\ time\ planned\ tecnique = \sum downtime\ because\ of\ codes\ 31\ to\ 33 \tag{4}$$

Down time planned auxiliary reasons:

$$Down\ time\ planned\ auxiliary\ reasons = \sum downtime\ because\ of\ code\ 41 \tag{5}$$

Down time unplanned production or process:

$$Down\ time\ unplanned\ production / process = \sum downtime\ because\ of\ to\ codes\ 51\ to\ 59 \tag{6}$$

Down time unplanned technical:

$$Down\ time\ unplanned\ tecnical = \sum downtime\ because\ of\ codes\ 61\ to\ 64 \tag{7}$$

Down time unplanned auxiliary reasons:

$$Down\ time\ unplanned\ auxiliary\ reasons = \sum downtime\ because\ of\ codes\ 71\ to\ 77 \tag{8}$$

Idleness:

$$Idleness = \sum downtime\ because\ of\ code\ 81 \tag{9}$$

Recently, Pinto (2008) has said availability production is the function below:

$$\Pr oduction\ availability = \frac{Period - \sum hours\ available}{Period} \tag{10}$$

4. TOOLS USED IN THE CALCULATIONS

Basic mathematical rules and Excel™ - Microsoft Co software were used in the calculations.

5. RESULTS

Figure 10 shown the amount of production units using the method since its release in 2005.

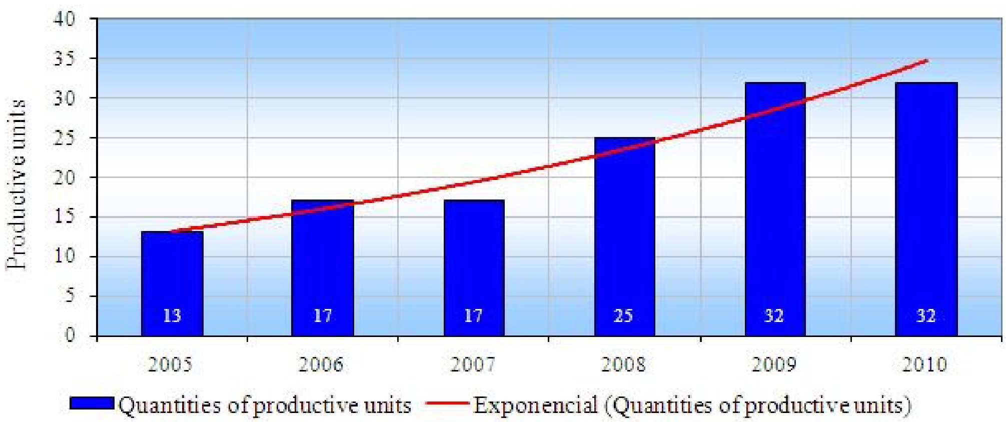

Figure 10. Quantity of production units using the method over the years.

Figure 10 illustrates the evolution of the method. The amount of productive units that in 2010 is 2,5 times greater than the amount in the initial step in 2005. The method was applied in all production systems of 32 productive units that have continuous or intermittent systems, which are divided into production and batch production custom.

Through the analysis of Fig. 10, it was concluded that the method is effective since it has increased 146 percents the area of use between 2005 and 2010. At this point, it is necessary to mention that over the years some of the codes currently used have been included in the method in order to cover the four production systems used. This process of discussion and analysis of stop codes has also brought confidence and empathy to the production areas, which are important items for the method to function properly.

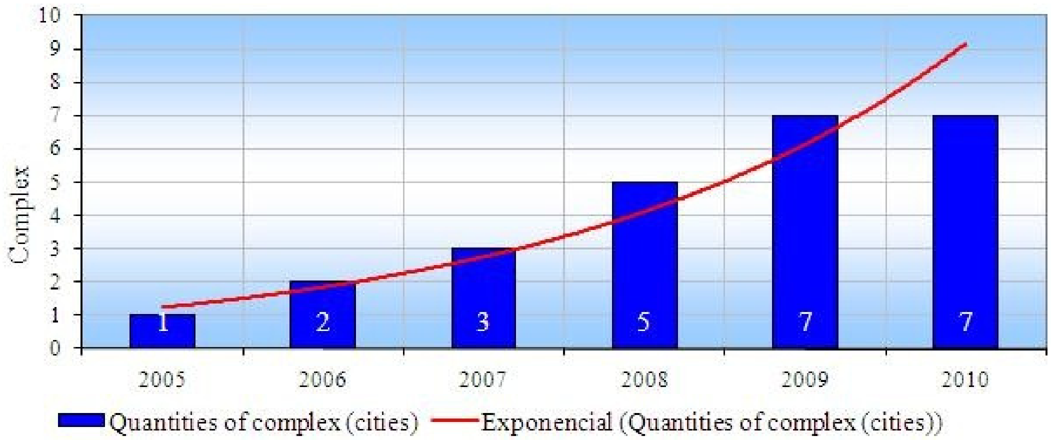

Figure 11. Number of complexes using the method over the years.

The second index is the number of complexes that have accepted this method, as Fig. 11 shows. It demonstrates that the method was applied in all production systems regardless of region since the seven complexes are distributed in four different states.

Figure 11 shows a 600 percent increase in the adherence of other complexes or plants, which represents a strengthening of the use of these indices at the highest managers in the organization.

After the normalization of the indicators in all plants in Brazil, this method has helped the organization make many decisions and correctly compare production units allocated in different regions of the country.

Currently the method is in process of translation so it can be expanded in South America.

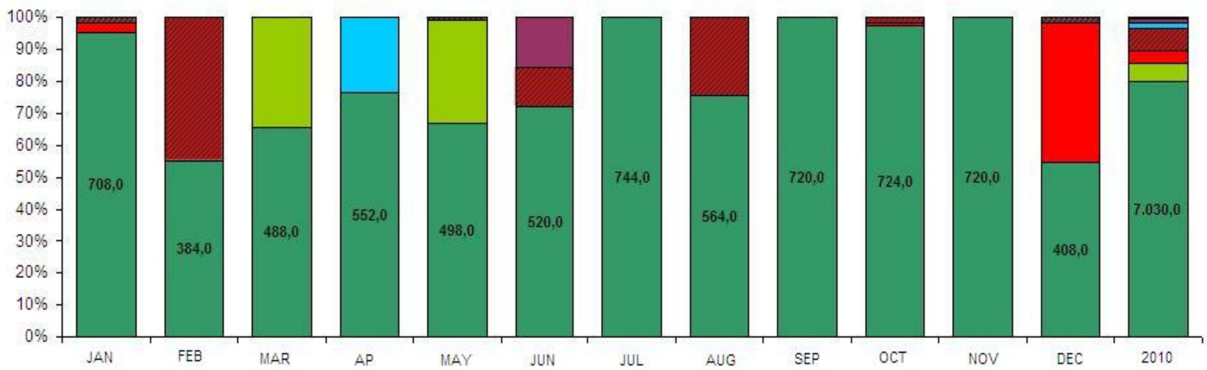

Figure 12. Annual graph.

Figure 12 shows the evolution of the availability in a production unit that has seasonal peaks of use. It can be concluded that the method is effective because it was able to measure changes in occupation and reasons that caused downtime and idleness.

6. CONCLUSION

This method is able to analyze reliable data and to support the company and optimize their investment by reducing costs and consequently, by obtaining financial returns above capital cost in addition to helping clients achieve further success through quick delivery of products.

Through the condensing of the existing theories of the market and interviews with those responsible for production unit and those responsible for the areas were the information would be used, it was concluded that the method was capable of measuring the availability of a plant or production unit, with consideration of the combined aspects of its mode of production, reliability, maintainability, logistics support, supply chain support and financial resources used. The method is able to compare the different plants or production units regardless of their production system or amount of resources used.

The specific objectives were achieved since the method was performed and literature on management information and maintenance method was presented for definition and calculation of availability.

It was defined and understood as the best solution for removal and application of the method in the flow of the business operations, and it was demonstrated that the method leads to the identification and correct classification of the causes for losses.

It was also identified that many situations in which the technical area more precisely maintenance were blamed for the decline in availability. However, the real reason for unavailability was the production because of operational errors, which overtuned the old paradigm: the machines are unavailable because maintenance is not effective!

7. ACKNOWLEDGES

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