PRODUCTIVITY: PRODUCTION MANAGEMENT SYSTEM IMPLEMENTATION IN A BRAZILIAN INDUSTRY – CASE STUDY

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Abstract. *The present field research about productivity management aims at different conceptual features and presents an investigation about the development of a productivity management system through an illustrative case study.*
The present work shows how important is to define clearly what productivity is (Goldrat 1990; Ostrenga et alli, 1993) and calls attention to the fact that productivity may have different approaches (Fry & Cox, 1989). It shows that productivity indicators can be absolutes or relatives (Bititci et alli, 1997) and those calculations are as important as the indicators themselves (Johnson & Kaplan, 1993). It claims that the productivity management may have a systematic approach (Crowe & Nuño, 1991, Goldrat, 1994) and that indicators may stimulate the learning process, and not punishments (Ginsberg, 1998; Sashkin & Kiser, 1994). It defends that is possible to interpret a indicators evolution through the variation theory (Deming, 1990; Correa & Slack, 1994) and shows there are different ways of improving productiveness (Sink & Tutle, 1993). It postulates that the productivity of a system is equivalent to productivity or constraint restrictions (Goldrat, 1996).This case study was developed in a Brazilian industry, which is part of an agricultural group. This group participates in many kinds of that business.

Keywords: *productivity, productivity management system, PDCA method, theory of variation, theory of constraints.*

1. Introduction

The idea of producing goods or services which generate more value than the cost necessary to produce them is the basic engine that moves the capitalistic economy. By definition, the more we generate value (results) with less cost, the more *productive* we will be. Thus, productivity is a key concept to reach satisfactory economic performance (Goldrat 1990; Ostrenga et alli, 1993).

Productivity has always been associated with the relationship between *results* and *sources* used. However, in the manufacturing environment, the initial focus was directed to the production of parts and the use of human resources, namely the use of direct workforce time in the production process. According to Zarifan (apud Soares, 1990), Taylor *has defined the increment of productivity as the diminution of the necessary time for performing the human work operations inserted in the actual production process*.

Despite its industrial origin, the concern about productivity has practically extended to all sectors of the economy. The managerial approach has increasingly been applied to several types of non-manufacturing works.

It is important to observe that productivity management has been changing over time and due to the competitive contexts. For example, industrial productivity has been incorporating several ideas and concepts of different management models, such as: TOC – Theory of Constraints, Theory of Systems, Total Quality Management, Total Productive Maintenance, Learning Organization, Project Management, and Adaptive Complex System. Therefore, it is a purpose of this work to demonstrate how different contributions to management can be considered and applied in the development of productivity management systems, such work including a case study for further illustration.

2. Change of productivity approach

The initial growth of the manufacturing industry was based on the intensive use of workforce. Such fact explains the still present focus on measuring productivity mainly according to the workforce resource. Similarly, due to the predominant Cartesian view which induced that, for one to understand the 'whole', one should treat it only by breaking into its 'parts', it was precipitately concluded that the increase of productivity in all and any part, both individually and independently, was enough for one to increase the productivity of the whole.

The intensification of complexity created by the use of integrated systems of equipment, by the increasing automation, the pressure on profitability due to competitiveness, quality demand, the need for flexibility and acceleration of production, has caused one to wonder and question some dogmas, such as: Is productivity measurement through production/man-hour the best way to measure productivity?; Does the productivity increase in the manufacturing area depend on efforts exclusive of such area?; Does the productivity improvement in all and any productive center result in higher amount of final products and better financial outcomes?; Should the non-productive time of a machine be accepted unconditionally as something inherent to the productive process?; Is the pressure only on workforce enough for productivity to increase?

Old ideas are mingled with new concepts to find better answers for the interaction of industry concrete reality, turning the development of management systems into something adaptive, which should be in permanent construction. Therefore, under the aspect of complexity, the continuous integration of knowledge originating from different areas and perspectives must be considered, in order to establish solutions that interact with the complex reality.

2.1. Fundamental Concepts

The present work uses herein a case study that relates to the implementation of and the results reached by a management system of productivity in a plant. Hence, the knowledge of some fundamental concepts that have been used in conceiving and implanting such system is necessary.

Definition of Productivity

As previously mentioned, productivity is established by the relationship between results / resources. However, regarding a system, it can be considered under a more comprehensive perspective (named global) or a more specific perspective (named partial), concerning both results and resources. In companies, the global perspective is dealt with by the financial language (invoicing/costs), and the partial perspective varies according to the area. The industrial area uses 'production/production resources' (being man-hour, machine-hour, and material weight the most used). It is also possible to consider productivity either in the absolute form (e.g., parts / man-hour of labor), or in the relative form (%). In such case, there must exist a standard measure of productivity previously established, which will be used as a denominator (e.g., effected productivity / maximum theoretical productivity).

Productivity and systemic view

In companies, regardless of how the industrial productivity is measured, one must be aware that, behind the indicator, there is a plurality of interrelated factors that affect the result obtained (Bititci *et alli*, 1997).

The experience in the industrial area shows us that the improvement in the productivity involves a complex net of causes which must be considered (Fry & Cox, 1989), such as:

- ❑ Product and process design
- ❑ Production programming
- ❑ Mix of products
- ❑ Work area organization
- ❑ Process understanding and control
- ❑ Supplier and raw material quality
- ❑ Communication between management and operational areas
- ❑ Material identification and handling
- ❑ Maintenance engineering
- ❑ Process engineering (for rationalization)
- ❑ Commercial policy
- ❑ Supplying policy (purchases and stocks)

Etc.

Standard Time and Productive Set

Standard time is the time regarded as necessary for a productive set to perform a *certain activity*, in normal working conditions, necessary to obtain a *production unit*. Such activity can normally be broken into a sequence of operations for analyzing and determining the *standard times*.

A *productive set* may be understood as an integrated set of transforming resources used in a process, which turns input into output. It can be a combination of man-machine, men team, integrated system of equipment, or any other combination form of transforming resources for carrying out a productive process, as long as the beginning and the end, as well as its inputs and outputs, are defined.

Production Flow and "Neck"

Every product is shaped through a sequence of connected transformations, i.e., along a *production flow* (or sequence of processes). When there are productive centers exclusively dedicated to the production of certain products, i.e., for performing only production flows of specific products, this set is called production line.

The theory of constraints reminds us that the production capacity of the final products equals the capacity of the productive center that has least capacity in the flow (called constraint or neck). Any production in the other productive centers exceeding the neck capacity before the neck creates intermediate stocks, once no exceeding final product is produced, since it is restricted to the neck capacity. Therefore, through the concept of neck, we can perceive that there is no use in improving the productive capacity of all and any productive center indistinctly, because a higher productive capacity of final products will only exist if we increase the neck capacity. Hence, in designing a production line, one of the main concerns is the balance of the capacities of the productive centers involved in the flow, which is called line balance. This balance is not always possible or feasible in practice, but the notion of neck is fundamental for the adequate management of the system. In order to deepen the knowledge about the theory of constraints, reading the books by Goldratt, the father of the pertaining art, is suggested.

TPM (Total Productive Maintenance) Indicators

With the development of productive processes based on the use of increasingly automated equipment, it is noted that, more important than controlling workforce time, is keeping equipment in production for the longest time. In this situation, productivity starts to focus on a resource that has become fundamental: the time-machine, and the proposal of TPM involves a definition of indicators for productivity management according to such perspective. This matter has become so fundamental that some understand TPM as standing for Total Production Maintenance.

The first step was to classify the times relating the equipment effective performance and to identify the main causes of low performance (initially grouped in 6 great losses). Figure 1 illustrates this approach.

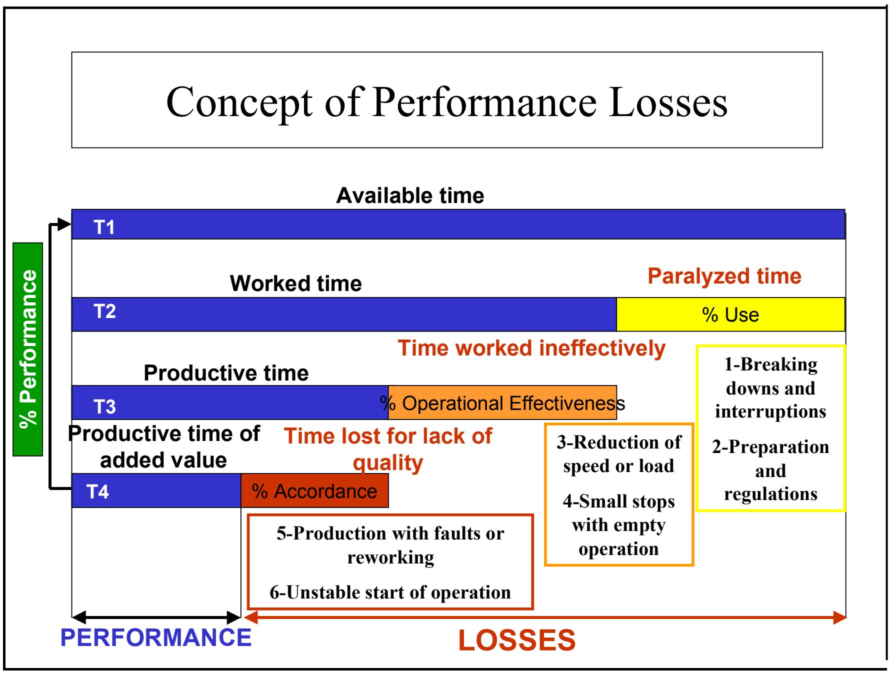


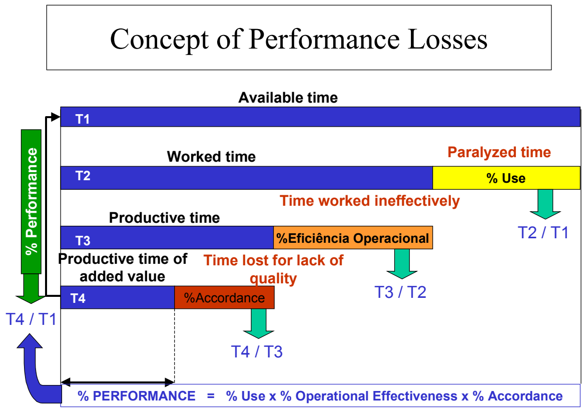
Figure 1: Concept of performance losses

- (T1)Available time: is the total working time, including extensions for overtime work (it may include or not lunch time and coffee-breaks – depending on the perspective of maximum utilization of necks).
- (T2)Worked time: is the working time subtracted from the paralyzed hours of the productive center, equals actual time spent for a certain production.
- (T3)Productive time: is the standard time in which the production effected could have been performed.
- (T4)Productive time of value added: is the productive time subtracted from standard times of production rejected due to lack of quality.

The final performance of the machine (T4/T1) is usually named, under the TPM aspect, OEE (*Overall Equipment Effectiveness*), and is calculated as a relative index, resulting from the multiplication of the partial indexes: % use (T2/T1), % operational effectiveness (T3/T2), and % accordance (T4/T2), as shown in Figure 2.

We can consider the development perspective directly through the production or relative productivity of the time-machine resource, by only considering the productions related to the times established and, in the case of productivity perspective, each production is always divided by the total available time, as show in Figure 3.

- (P1)Maximum theoretical productivity: is established by the following relation: maximum theoretical production / available time. As the maximum theoretical production is calculated by: total available time / standard time, we notice that maximum theoretical productivity is: = 1 / Standard Time.
- (P2)Theoretical Productivity in worked time: is established by dividing the maximum theoretical production in the time worked (= worked time / standard time) by the available time.
- (P3)Apparent effective productivity: is established dividing the production effected (with and without quality) by the total available time.
- (P4)Value productivity: is established dividing the production approved, i.e., with quality, by the available time.



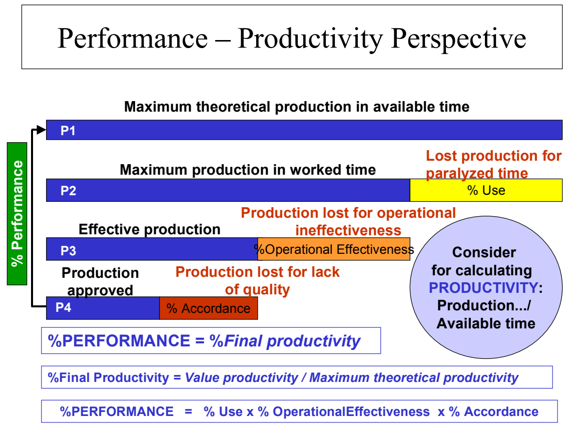


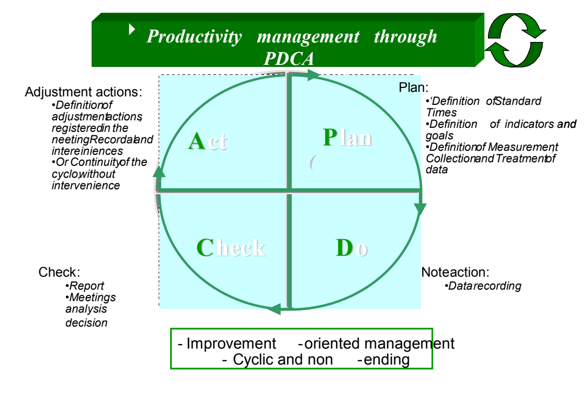
Figure 2: Concept of Performance Losses Figure 3: Performance: productivity perspective

The indicators are calculated in the same form as the previous one: % use = P2/P1; % operational effectiveness = P3/P2; % conformity = P4/P3, and the performance (which would be the final productivity, calculated in the relative form) would be the result of the multiplication of the three previous indicators (equivalent to P4/P1).

PDCA Method

One of the major contributions to the movement of Total Quality, introduced by Deming and propagated by the Japanese, was the PDCA cycle (Plan, Do, Check: verify and analyze, i.e., study, and Act: act afterwards in view of the results).

In Figures 4 and 5, we can notice the PDCA cycle applied in a productive system, Figure 4 presenting its general representation, and Figure 5 including the productive system, which is shown represented as a productive system, which turns inputs into outputs and generates data for the informational cycle of PDCA (adapted from the managerial system of Sink & Tutle, 1993).



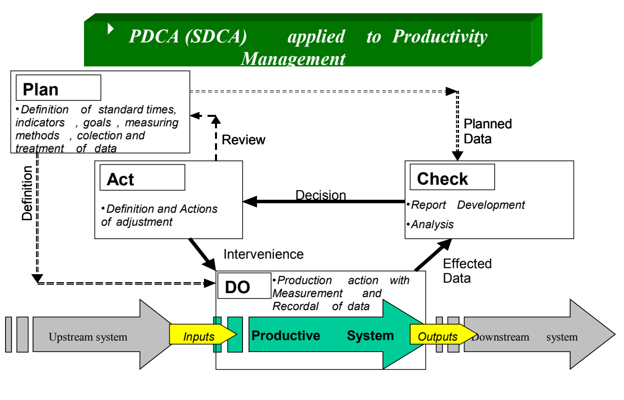


Figure 4: Management through PDCA Figure 5: PDCA applied to productivity management

It is important to point out that, as the productive cycles are repeated, and as a consequence of PDCA cycles for control, a process history is started which enables deeper analysis. Therefore, it is interesting to create movements that allow a wider reflection of the productive system. Taking into account that it is a dynamic system, the premises and the contextual references (both inner and outer references) that served as the base for its conception must be analyzed periodically, and the more complex interrelations, distant in time and space, that may be affecting the productive system being analyzed, must be more deeply studied. To this effect, it is proposed that the reflection cycles of PDCA, overlying the control cycles of PDCA, thereby forming a double loop, be used, according to Figures 6 and 7.

In implanting management systems of productivity, it is common to establish analysis meetings (check) for the control cycle, with differentiated consolidation and periodicity of data for the different hierarchic levels. Reflection is already expected to exist at such moments, being other situations likely to be created for motivating the individual and collective reflections, involving several levels, once, unlike the control, the reflection does not require much structuring. See in Figure 7 an example of differentiated periodicity for control meetings, in different hierarchic levels, for the analysis of productivity.

Theory of variation

Another great contribution from Deming, in the Quality Total movement, was the propagation of the theory of variation, which is based on the use of statistics. According to Deming (1997), “life is a variation”, which means that any productive process will present variability due to the several factors that affect it. Hence, we can expect variation over time regarding the results of productivity measurement

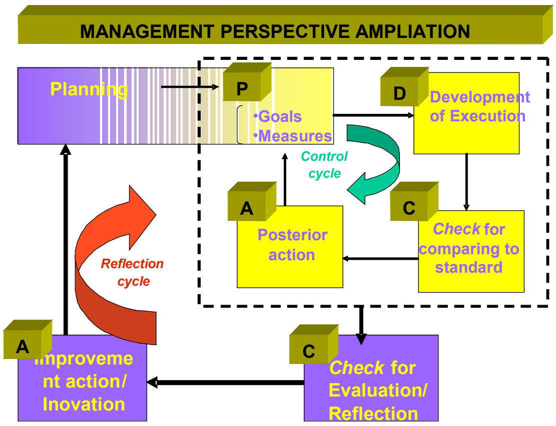


Figure 6: Management through PDCA

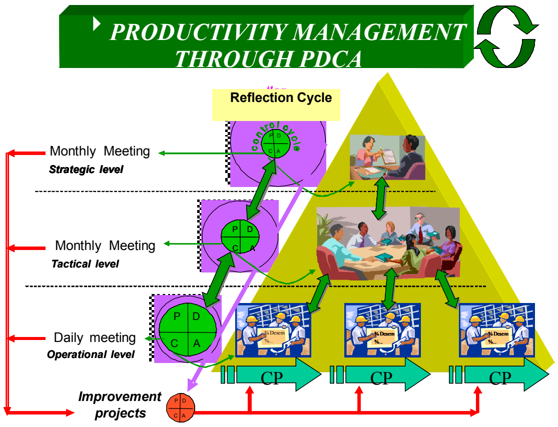


Figure 7: productivity management through PDCA

The fact of the matter is to know how to interpret such variation in order to generate the suitable learning about the process, as well as the adequate managerial actions. That would be the same as Deming’s statement that “we should know “what variation is trying to tell us about the processes”. For that purpose, the causes can be divided into two groups: *ordinary causes* and *special causes*.

Ordinary causes provide for an expected condition, i.e. predictability, due to a “stable variation”, considered *normal* under the point of view of statistics. This is because of the permanent acts of different factors ordinary to the process, whose final combination provides a stabilized variation (see Figure 8, variation of an amount of faults). It is possible to improve a stabilized situation by altering its level of current development, and/or by reducing the spectrum of its variation. In both cases, it is an action upon the system, which necessarily requires acting on the managerial levels (tactical and/or strategic). The special causes, on the other hand, create an outcome that is out of the variation considered normal, being always caused by a specific cause, more easily identified. Its elimination may need acting only on the operational level, involving or not management levels.

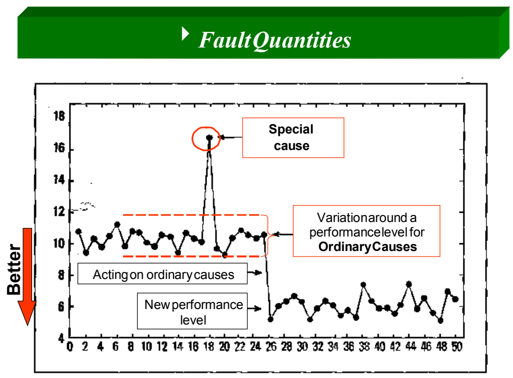


Figure 8: Example of faults quantities

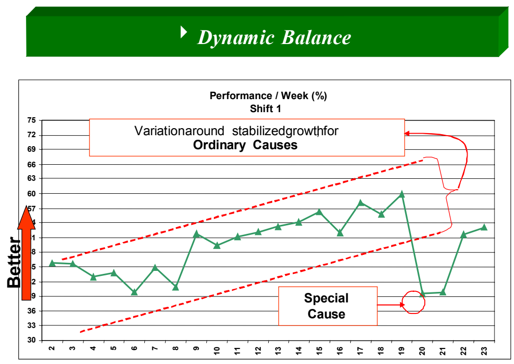


Figure 9: Example of dynamic balance

Stabilization around an “average pattern” (as shown in Figure 8), relatively fixed, is typical of a system that is “under statistic control”, upon which one establishes (naturally or through management acting) a control cycle directed to the balance circuit, within which the negative feedback occurs. However, there are situations in which the search for constant improvement, involving change of the performance level, takes place so integrated with the control (due to permanent reflection) that a dynamic balance is established, characterized by a circuit of information and of action directed to reinforcement (growth or “reduction”), typical of a positive feedback. In the latter, we can visualize the dynamic balance presented on Figure 9. In such case, the so-called normal variation has its ordinary causes relating to a circuit of constant reinforcement, happening until week 20, when something special happened. The impact of this especial cause seems to have created difficulties to reach previous levels, which would indicate that acting upon the special cause was either adequate or there was a change in the system, which may start to have a new characteristic of performance evolution.

3. Case study

For the purpose of demonstrating the application of the concepts previously shown, we present hereinafter a case study of the implementation of a productivity system in a feedstock factory, highly automated and characterized by production lines. The factory is installed in Brazil and is part of an agriculture and cattle raising business group that, besides owning other factories, also acts in other related business.

The beginning of the project happened on November, 2001, the use of indicators and management reports starting on march, 2002. The reasons for searching for a management system were: need to respond to an expected growth of demand; existence of a productive potential that could be exploited in a better way (such belief was due to the nominal capacity of the equipment); need to minimize stoppages occurred due to equipment operational faults; and, finally, importance of productivity in the market into which the company acts.

Regarding the productivity management, the existing situation was the following::

- The company used the following indicators: Production (ton)/ for shift-month (for monthly analysis), production (ton)/hour-man of production (which was also analyzed monthly), and amount of wrong mixture (ton)/ total amount produced (ton) (%, also analyzed monthly). The base for the quantitative parameters used as reference for posterior evaluation of the improvements provided by the projects are presented on Figure 10.
- The operational definition of how the denominator of production/man-hour indicator was not clearly established (there was some variation caused by the verification criterion).
- The measurement methodology of production(ton)/man-hour and amount of wrong mixture(ton)/total amount produced indicators was not reliable.
- The production(ton)/ per shift-month and production/hour-man indicators could be affected by the demand and could present drop, independently of any manufacturing effort or managerial competence.

INITIAL SITUATION

QUANTITATIVE PARAMETERS

PRODUCTION	PRODUCTIVITY	WRONG MIXTURE
maximum reached 2001 (July)	average month 2001 (Jan - Aug)	average month 2001 (Jan - Aug)
7.947 t in 3 shifts	0.56 t / hh (of production)	0.67 %
2.649 t / shift		

Figure 10: Initial situation

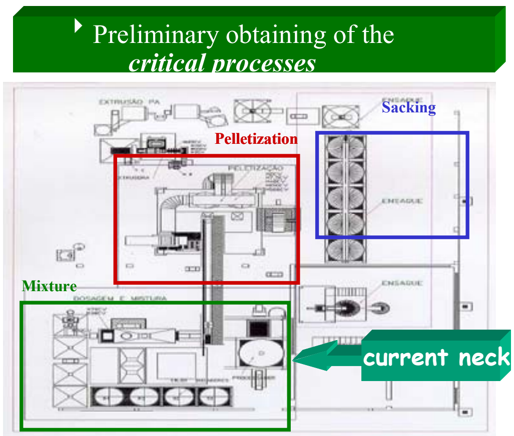


Figure 11: Critical process

It was observed that the use of indicators measured only monthly did not provide for adequate managerial acting. Similarly, due to the existence of automation of the main equipment, the absence of indicators relating to hour-machine did not permit an orientation for the managerial action, which ended up being concerned about the reduction of workforce in the secondary and support processes (intending to improve the ton/hour-man indicator), thereby deviating from the focus on improving the "neck" equipment.

The project started with an evaluation of the organizational environment of "plant floor" (materials and personnel) and of the main information flows relative to the production programming and control (PCP) of stock (of inputs and finished products). Through the survey of factors relating to the productive system, several plans of action were prepared to improve the conditions of production organization.

While some certain improvements were implanted, the main groups of products were identified (curve ABC), the sequence of production thereof were defined, and the processes regarded as critical were determined (Goldrat, 1996). Through the standard times (established by a chronological analysis), the current neck was identified as the process effected in the productive set called "mixture" (Figure 11). The mixture process was considered critical because the mistakes there observed they decreased the quality and they increased the costs. Hence, we opted for initially structuring the management system of productivity on the above mentioned productive set.

Therefore, the PDCA (with double loop of learning) was structured as shown in Figure 12. The control cycle comprised: (P) definition of standard times, of indicators (%use, %effectiveness, % conformity, and %performance) and of the methodology of measurement and reports development; (D) record of production, reasons for stops and rejected batches; (C) systematization of daily, weekly, and monthly meetings, using reports of indicators for analyses, (A) meeting records in order to define the adjustment actions and to guarantee the implementation thereof.

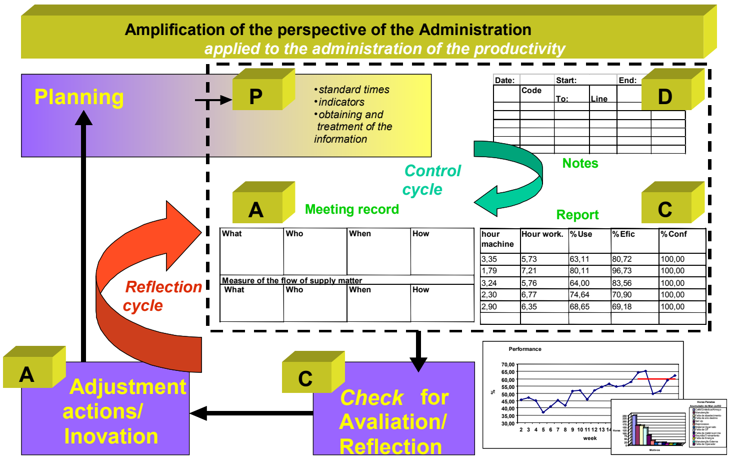


Figure 12: Reflection cycle

In Figure 12 is also present the reflection cycle, whose objective is performing analysis of indicator evolutions and reevaluate the system premises (standard times, current neck, etc). The reflection cycle differs from what is already normally done in way of measurement, analysis and improvement because it has a strategic approach (gone back to the future) instead of a control approach (gone back to the present).

The management system using new indicators directed to hour-machine (%use, %operational effectiveness, % conformity, and % performance), with meetings for analyzing short time intervals (from daily reports per shift), generated a significant growth over the previously existing indicators of Production(ton)/shift-month and Ton/hour-man, since its implementation in March 2002. The improvement on performance had already been observed by the actions taken from the resulting orientations of the initial analysis (see Figures 13 and 14).

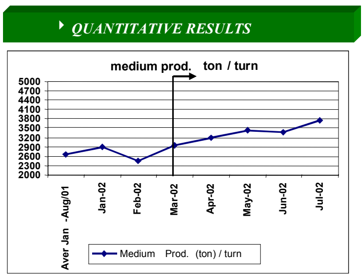


Figure 13

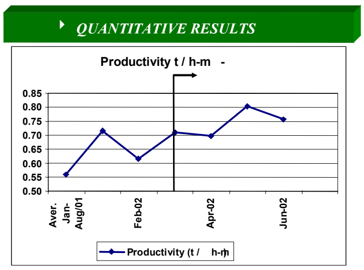


Figure 14

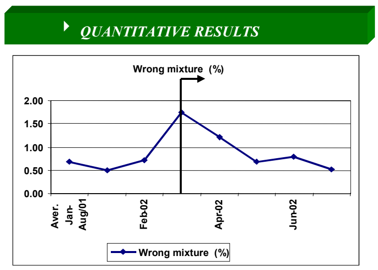


Figure 15

Regarding the indicator of wrong mixture (see Fig. 15), the supposition that the previous measurements were not reliable was confirmed because, although there was a great amount of wrong mixture in the warehouses, the registrations of measurement did not match, in such a way that, in implanting the management system, the production of wrong mixture amount was apparently raised (in fact, started to be registered), and later presented a real drop due to the actions taken.

The use of the new set of indicators directed to hour-machine resulted in a significant improvement of the parameters used as reference at the beginning of the project. Also, the management focus on improvement of neck performance impacted on the performance improvement in the plant as a whole (see Figs. 16 and 17). However, a more detailed analysis, which uses one evolution per week, indicates that there still exists instability in the system, but the learning has allowed the restart of the performance growth.

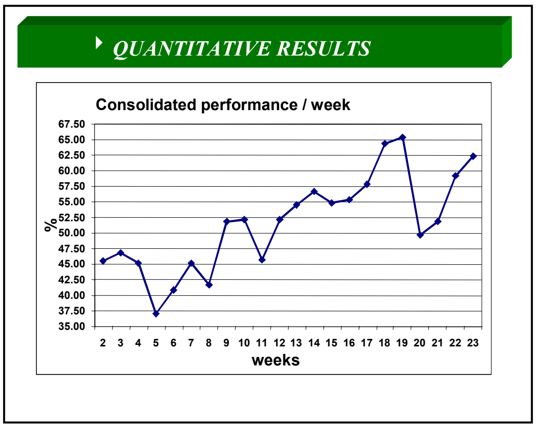


Figure 16

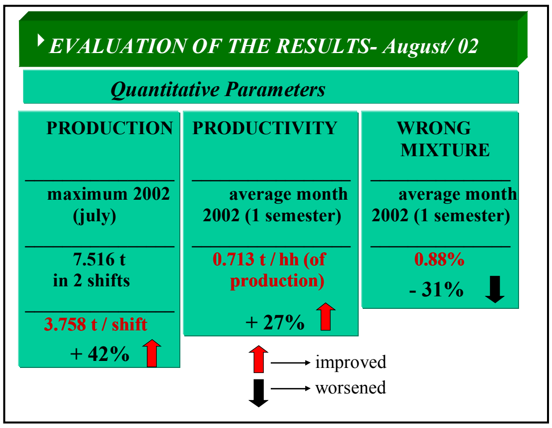


Figure 17

4. Conclusion and final contribution

Through the presented case study, it is possible to note that the industrial companies in managerial situations similar to the case will be able to obtain significant gains by adopting management systems of productivity based on the conditions presented above.

In order to summarize the main ideas presented and to present some careful steps that must be taken in relation to the management of productivity, we list below some generic principles that we deem important to be understood for structuring any management system of productivity, many of which are interrelated:

1. *The productivity of a productive system is equivalent to the productivity of its constraint (or neck).*
Any productive system has some constraint(s), which limit(s) the total productive capacity, which makes the productivity of the system equivalent to the productivity of the constraint(s). In other words, all the productive resources that are not a constraint naturally have an idle capacity, and a production that is higher than the constraint capacity will only generate intermediate stocks, and not final products.
2. *It is important to have a clear definition of productivity.*
The productivity of a system is always established by the relationship between: *results* generated (outputs) and *resources* used (input) by the system (result/resource or output/input), but there must be a clear operational definition of what the numerator and the denominator of the index(es) comprises.
3. *Presenting productivity as a numerical indicator and understanding it as a result of a system.*
Productivity is usually represented by an index, which presents a numerical indicator of the productivity level. But, be careful. As Deming said: *productivity measurement does not necessarily lead to productivity improvement.* Productivity is a result of the processes of working and managing. Only through the participation of the people involved in the system and the increase of process knowledge is productivity improvement promoted. One should remember that the causes and effects of productivity variation may be distant in time and space, and from the direct relationship with the focused resource itself. For example, Craig & Harris (apud Sumanth, 1984), mention the case in which an improvement of raw material quality could generate an erroneous interpretation of better performance of people, when a productivity indicator relating to workforce is being used. An example of the related consequences could be when an industrial productivity increase is reached, generating a stock increase of low turnover products.
4. *The methodology to calculate the indicators is as important as the indicators themselves.*
As important as defining the productivity indicators is defining the methodology to collect and treat them: the operational definition of the indicators, the way to establish patterns or goals, the way to measure variables, the data processing, the generation of managerial information, the analysis and the intervention in the system. The productivity indicators presented in the relative form (%) have been used mostly to motivate managerial actions, once it relates to effective productivity to a standard theoretical productivity (an implicit goal of what is possible).
5. *Productivity management demands systemic reasoning.*
In order to manage the performance of a system adequately, the productivity measurements must have a wide focus, being important to use several indicators combined, so as to assure a systemic focus. In order to manage manufacturing performance, one could consider the use of productivity based on the machine resource together with other productivity measures based on material resources and workforce, as well as the relation with the global economic indicators.
6. *Productivity indicators shall motivate learning, not punishment.*
A management system of productivity shall provide for performance improvement, by encouraging permanent learning (turning PDCA) and, consequently, continuous improvement. It shall not become a punishment instrument.

7. *Indicators depend on people in order to be a managerial instrument.*
A management system of productivity does not replace the need for people capable of solving problems and of deepening their knowledge in the working processes. Productivity indicators can be nothing but numbers and graphics, unless there are people capable of interpreting them and taking managerial actions. People should be mainly prepared to interpret the indicators evolution through the "theory of variation", proposed by Deming.
8. *The use of specialized personnel for support together with the operational team can generate significant gain..*
It can be corroborated by the indicators that the productivity increase of direct operational work is worth some investment on indirect work, such as: engineering, information science, and higher acting by directorship over control and analysis.
9. *The implementation of a management system of productivity must be carried out as a project.*
The development and implementation of a management system of productivity involve a significant change in the management routine. This implies taking into account a significant increase of complexity in the technical and behavioral aspects in the work environment. That does not mean an increase on complication or entanglement; on the contrary, it means an increase of the capacity of interacting with the company reality and providing higher quality solutions. And, for its complexity, it must be treated as a project and, as such, managed with the required care.
10. *There are different ways to improve productivity.*
Productivity can be improved through 5 basic ways, as Sink & Tutle (1993) present in Chart 1. But, whenever possible, consider first the possibilities of results increase, once, as Goldratt, the father of the theory of constraints, would say, a company exists to generate gains and not to generate cost reductions.

	Result (Output)	**Resource (Input)**	**Productivity improvement**
1	**Increases** ⇧	**Decreases** ⇩	---------------------- -
2	**Increases** ⇧	**Remains constant**	---------------------- - =
3	**Increases** ⇧	**Increases, but with less intensity** ⇧	---------------------- -
4	**Remains constant**	**Decreases** ⇩	= ---------------------- -
5	**Decreases** ⇩	**Decreases, but with more intensity** ⇩	---------------------- -

Chart 1. Basic ways to increase productivity (Sink & Tutle,1993)

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