

Study of the adaptations to the Total Productive Maintenance reference model for companies in Brazil and resulting organizational impacts

José Ricardo Scareli Carrijo¹, Carlos Roberto Camello Lima²

¹(Instituição Toledo de Ensino – ITE, Bauru, SP, Brazil)

²(Methodist University of Piracicaba, Santa Bárbara d'Oeste, SP, Brazil)

Abstract:- Considering the importance of increasing competitiveness in Brazilian companies in order to compete on an increasingly globalized market, it is necessary to better understand the emerging management techniques and tools capable of maximizing the use of resources available to the organizations. This work focuses on the concept of TPM – Total Productive Maintenance, originated in Japan, and its application and implementation in Brazilian companies. For this purpose, its origins were analyzed, as well as the process of dissemination through TPM Awards criteria – created by the Japanese Institute of Plant Maintenance - and its spreading and adoption by companies as a competitiveness tool. The conceptual structure was built as a result of a broad bibliographic review involving knowledge about the subject and through structured dialogue with executives, engineers, operators and production helpers in Brazil. This structure was used to conduct a multiple case study with four Brazilian companies from different segments as field research. Practical applications of the concepts of TPM have been observed, as well as its dissemination and implementation processes and the adaptations made to the organizational culture of each company. The main contribution of the work is to enable the understanding of the implementation steps and the perception of TPM and its effects on the business environment by the various organizational levels.

Keywords:- Brazilian Industries, Quality, Productivity, Total Productive Maintenance, TPM.

I. INTRODUCTION

Brazil has experienced over the two last decades an economic insertion in the process of market globalization. Brazilian companies are constantly searching for ways of increasing competitiveness through advanced management practices and foreign organizational technologies, based on reference theory models already tested in developed countries.

Therefore, in recent years, fads have become common in companies of the productive sector to represent philosophies, tools and initiatives in this search for competitiveness through quality improvement. This has led to rapid changes, adaptations to the new reality and an increasing interest in models that provide greater productivity.

Defining this new environment of organizational behavior and fast adaptation demand, Robins [1] established that nowadays successful organizations need to infuse innovation and master the art of changing or else they will be candidates for extinction.

Caldas and Wood Jr. [2] have defined the concept of organizational anthropophagi, which deals with the assimilation of foreign technologies, with a creative adaptation method and an unprejudiced conscious practice to guarantee appropriate adoption, i.e., adequate to the local specificities of foreign management technology that carry useful knowledge to emerging countries.

Therefore, it is important to investigate how Brazilian companies using Total Productive Maintenance (TPM) reference model have been processing the adaptation of this philosophy originated in Japan and how their actors of different organizational levels perceive these changes in the company environment. Such investigation, not only provides a better understanding of the TPM organizational adaptation process and its deployment in the activities related to each phase of the pillars development, but also intends to list its impacts on manufacture performance indicators achieved by the analyzed companies.

The main idea of the program is the complete elimination of the losses represented by breakdowns, set-up time, cycle loss, minor stops, scrap, rework, and instability during processes in the beginning and end of shifts.

TPM's way of implementation was globally spread by the Japanese Institute of Plant Maintenance (JIPM) and by TPM Awards criteria, based on the concept of activities organized by pillars [3]. This way of

analyzing the set of actions structured by the organizations stimulates the search for excellence levels in various organizational areas during the implementation processes.

The eight pillars that enclose these activities are denominated as: Autonomous Maintenance, Planned Maintenance, Education and Training, Quality Maintenance, Individual Improvement, Safety/Hygiene and Environment, Preventive Management (Initial Control) and Administrative Area Management (TPM Office). Each one has its own way of being developed, structured in well-defined phases that correspond to a set of actions organized to be implemented and adapted by the organizations.

Companies using TPM reference model go through the implementation process in different ways. Based on consulting orientation, visits to other companies already practicing and sharing the concepts in courses and trainings about the theme, each company adapts a set of practices to its own reality and goes through the stages of the preparation model for the TPM Awards, developed and released by JIPM.

Therefore, adaptations in the implementation project already developed by Brazilian companies that use TPM reference model may be a rich source of information that allows beginners to find ways of overcoming organizational resistance and achieving results with an increase in competitiveness and productivity. Therefore, that is an opportunity to share good practices and techniques used by companies already adopting TPM in Brazil. This democratization may help to increase competitiveness and productivity of a wider number of organizations of different sizes and areas.

1.1 The use of reference models in the search for competitiveness

Defining TPM, Nakajima [4] established that it is a global industrial maintenance system based on the human capacity and the participation of everyone to maximize the use of assets. For the same author, TPM is an industrial maintenance philosophy adapted by the Japanese companies as an organization and management system based on small improvement groups through their own initiative.

It is a managing system that identifies and eliminates existing losses in the productive process, maximizes the use of the industrial asset and guarantees a generation of high quality products at competitive costs. Besides, it develops knowledge capable of reeducating people for preventive actions and continuous improvement, guaranteeing equipment reliability and process capability without additional investment.

According to McKone, Schoroeder and Cua [5, 6], TPM is designed to maximize equipment effectiveness increasing their global efficiency and establishing a closer relation among maintenance and production systems, expanding the operating life of the equipment, with the participation of all employees, from top management to factory floor workers to promote productive maintenance through motivational management and volunteer participation of the small groups of activities.

To magnify TPM's concept as something strategic and surround, Tajiri and Gotoh [7] established that TPM is an strategy adopted by all the people directly involved with manufacturing to achieve Zero Accident, Zero Defect, Zero Breakdown. Solidifying TPM's organizational amplitude, Seth and Tripathi [8] established that TPM also represents employee involvement, interdepartmental approach, diffusion all around the organization and continuous improvement.

According to Shirose [9], TPM, a unique system of managerial knowledge, was developed in Japan based on the concepts of PM (Productive or Preventive Maintenance) methodology, originated in the United States of America between the 1950's and 1960's. TPM concept has evolved, since the 1950's, right after World War II, when Japan started rebuilding the country with the support of the United States of America after the devastation by the effects of the atomic bomb and the destruction caused by the war.

According to Liker [10] TPM is a method that everyone learns how to clean, inspect and maintain equipment with the objective of reaching a high level of stability in the productive operations.

Since 1971, JIPM has focused the use and dissemination of TPM methodology in companies in Japan and other countries, with the objective of reducing losses and improvement of operational results.

According to Robinson and Ginder [11], JIPM, initially focused on awarding only Japanese companies, developed excellence criteria to recognize good practices in companies, as showed in Table 1.

Table 1. JIPM's excellence criteria – TPM Awards [11]

| Value/Pillar | Concept |
|---------------------------------------|--|
| TPM Organization and Operation | <ul style="list-style-type: none"> • Relation between the company's general policy and TPM • TPM policy and objective development • TPM promotional organization |
| Individual Improvement | <ul style="list-style-type: none"> • Loss structure clarification • Relation between improvement and results • Progress and improvement activities quality |

| | |
|--|--|
| Autonomous Maintenance | <ul style="list-style-type: none"> • Equipment basic conditions recovering and inspection methods • Stages development • Autonomous maintenance activities effects |
| Planned Maintenance | <ul style="list-style-type: none"> • Work allocation between planned and autonomous maintenance • Maintenance program and its cost reduction • Use of predictive equipment |
| Quality maintenance | <ul style="list-style-type: none"> • Quality maintenance deployment • Patterns to eliminate defects and root cause analysis |
| Preventive Management of Equipment and Products | <ul style="list-style-type: none"> • Preventive maintenance in the projects • New products and equipment management |
| Education and Training | <ul style="list-style-type: none"> • Matrix of skills and educational system for managers, assistants and operators. |
| Administrative areas | <ul style="list-style-type: none"> • Stock and work reduction in the process • Information transmission speed • Cost reduction |
| Safety, Hygiene and Environment | <ul style="list-style-type: none"> • Policies, organization and results in safety, hygiene and environment • Accident analysis and recurrence prevention |
| TPM effects and results | <ul style="list-style-type: none"> • Comparison of goals and results obtained with TPM • Assimilation of TPM as management tool and future plans |

In 1971, Nippodenso, a Toyota's provider company, was the first Japanese company to receive the JIPM's Excellence Award as recognition to its good maintenance practices. This award process was one of the embryos in the creation of a reference model for TPM concept usage. The first company to apply for the TPM Awards – JIPM in Brazil was Pirelli Cables (SP), in 1995, probably motivated by the award received by its subsidiary in Turkey the year before.

Many companies in Brazil, as mentioned by Ribeiro [12], have TPM implementation process already consolidated. Several of such companies are subsidiaries of intercontinental groups. Analyzing the influence of the environment on the development of TPM techniques, Mckone, Schroeder and Cua [5] stated that the organizational and managerial environment must be considered during TPM implementation process. They also realized in their own research that environment context factors such as country help explain the differences in TPM implementation process. Also reinforcing the need for adaptations, Hartman [13] emphasizes that to successfully apply TPM in a non-Japanese company one must look first at the existing differences concerning work ethics, managerial style and cultural context.

Researching the effects of TPM implementation in companies, Cua, Mckone and Schroeder [14] found strong evidence that TPM has a positive and significant relation with low costs, high quality levels and consistent performances of delivery.

Ribeiro [12], focusing the need for adaptation to the Brazilian reality, considered that TPM must be implemented respecting the countries, region, and companies culture and not as a canned product. Therefore, adaptations must be done not distorting the original concepts.

Therefore, through a multiple case study, this work analyses TPM's implementation impacts, its form of spreading and how creative adaptations have been processed in the traditional model for the application in companies in Brazil. The work also discusses how this process has affected the environment on companies and on their various organizational levels.

II. METHOD AND RESEARCH PROCEDURES

According to Marder [15], in scientific research the choice of the method depends on a philosophical posture about the possibility of investigating reality. Therefore, this work investigated concrete experiences of TPM implementation, developed by some companies in Brazil, with the objective of elaborating an analyzing the implementation way, under the perspectives of many organizational level actors, compatible to the organizational reality in our country.

Concerning the objectives, this is an exploratory research, which hopes to outline the application ways of a reference model. This is also a descriptive research, once it observed the facts, recording, analyzing and classifying them.

For Gil [16], this type of research has the objective of providing better familiarity with the problem, in view of making it more explicit or constitute hypothesis. In most cases, these researches involve: A) bibliographic research; b) interviews with people who had practical experiences; and c) analysis of examples that stimulate the comprehension”.

In this work, the multiple cases study was used with the object of magnifying the scope of the scientific investigation and corroborating with Yin [17] to whom after revealing a significant finding from a single experiment, the immediate object of the research will be to replicate this finding, conducting a second, third or even more experiments.

The technical choice of the multiple cases study for this research is justified by its ability to explore social processes as they evolve inside the organizations [15].

Applying the multiple cases study in this research allowed an analysis of how TPM adaptations – through the various actions performed in the pillar implementation activities – developed in each organizational context and which meanings are being construed inside organizations.

Finally, the “analytical generalization” was used, as proposed by Yin [17], in which a previously developed theory is used as model to which the empirical case study results must be compared. For the analysis of the obtained results, the excellence criteria in each pillar, established by the JIPM annually for the TPM Awards [3] were used as basic model. These criteria correspond to the *state of the art* in the pillar activities development and have served as the basis for the companies using TPM to verify the stage in which they find themselves in relation to the companies awarded with excellence in organizational practices.

2.1 Procedures

For the investigation, a wide research in literature sources, document and *ex post fact* search were initially made, also evaluating data indicators, information and evidence obtained during visits to four different industrial plants.

Obtained data were interpreted qualitatively and quantitatively, with more emphasis in the use of qualitative instruments, considering the nature of the proposed investigation. Interviews were semi-structured and to collect the actor’s views of different organizational levels, questionnaires were used with open and closed questions. These multiple methods of information collection were used in a manner to enable the triangulation of evidence.

Primary data were obtained from two questionnaires: the first, applied to the directive level of the companies (Directors, Managers or Coordinators), with open and closed questions, and the second, with closed questions for the operational level.

Questionnaires had questions aiming the identification of the organizational actor’s perceptions in relation to how TPM is treated in each company; identification of the respondent sector; if the respondent had subordinates or not; and how long did he belong to the company’s staff; if he belonged to an autonomous maintenance group; and what are the perceptions of each respondent concerning the effects generated by TPM in relation to knowledge, quantity and quality of work, breakdowns and safety, physical work environment and ,finally, the relationship with superiors and colleagues.

Employees admitted after the beginning of TPM activities, as informed by the companies, were excluded. Data obtained from questionnaires were processed using *SAS (Statistical Analysis System)* software and Excel®.

Concerning evidences, the following materials were searched: documents, records in files, direct observations, interviews and physical artifacts that would enable the identification of actions related to the various stages of the implementation process.

2.1.1 Analysis of Units

Participants of this research were employees from four different Brazilian companies all localized in the state of São Paulo: i) a printing industry (Company A); ii) a food and energy industry (Company B); iii) a paper and pulp industry (company C); and iv) a manufacturer of cconstruction and mining equipment (Company D), organizations that already have TPM implementation process and were selected because of their importance in the respective business areas.

A pilot case study was performed with one of the companies, selected due to the longest time using TPM. This pilot study had the objective of identifying possible difficulties obtaining information and “improve plans for data collection, not only concerning to content but also the procedures that must be followed”, as reinforced by Yin [17].

III. COLLECTED DATA ANALYSIS AND OBTAINED RESULTS

Data collected from the companies were analyzed both qualitatively and quantitatively with the presentation of descriptions, comparisons and relationship between them and the set of theory concepts and secondary information concerning the work's theme.

First, companies were analyzed individually (vertical analysis or by unit analysis) and secondly in group (horizontal analysis or by question). After the presentation of each company's individual data, a group analysis was designed, establishing interrelations among the cases to ensure greater reliability to the collected information.

As internal and external validation of the construct, as well as confirmation of its reliability, some measures were adopted:

- data collection analysis patronization;
- use of several evidence sources to analyze data;
- use of literal replication logic;
- analytical comments made simultaneously to the data presentation in each paragraph;

To evaluate the variables of the questionnaire applied to the operational level, 10 variance analysis were developed, one for each variable, and those analyzed were: education/time in the company/ sector/ perception concerning breakdown reduction/ perception concerning knowledge level/ perception concerning safety / perception concerning the physical environment / perception concerning improvement in the relationship to colleagues/perception concerning the relationship to superiors.

To evaluate the variables of the questionnaire applied to the managerial level, four variance analyses were developed and the aspects analyzed were: TPM as management method; TPM as competitiveness guarantee; TPM as a way of guaranteeing better personnel involvement; and finally, the variable related to the involvement of managerial areas in the program implementation process.

IV. DISCUSSION OF RESULTS

To provide synthesis of the presented cases, Tables 2 to 5 show the basic characteristics of each TPM implementation program and other relevant data. Information is presented vertically, company by company, and also horizontally, considering the main implementation aspects analyzed.

The units of analysis are all traditional and consolidated companies, medium and large sizes, located in the main Brazilian economical region, acting in different sectors. The companies have different constitutions and management oscillates between familiar and professional.

It is possible to observe that all the companies analyzed began TPM activities as top-down, i.e., by determination of the high administration, with the support of external consulting to absorb knowledge related to TPM and managers had access to methodology through overseas visits or by determination of the foreign headquarters. Experience exchange with other companies applying TPM is well used and the kick off activity, except for Caterpillar, was an important landmark for the assimilation of TPM's beginning activities.

Table 2. Managerial Context: case information summary

| | Company A | Company B | Company C | Company D |
|--|----------------------------|-------------------------|----------------------|-----------------------------|
| Foundation Year | 1950 | 1946 | 1961 | 1960 |
| Employees | 1.100 | 1.200 | 750 | 4.900 |
| Sector | Publishing and Information | Sugar and Alcohol Plant | Packing | Automotive: Tractors |
| Capital | Brazilian /South African | Brazilian | Brazilian | North - American |
| Company's Constitution | Joint Stock Company | Closed Capital | Closed Capital | Open capital |
| Market | Brazil | Brazil and Overseas | Brazil | Brazil and Overseas |
| Management | Family/ Professional | Family/ Professional | Family/ Professional | Professional |
| Ranking by Sales (Exame Magazine) | 202 | 676 | 750 | 135 |
| Revenue 2006 | MU\$ 764 | MU\$ 188 | MU\$ 163 | MU\$ 1.136 |

Table 3. TPM activities structure: implementation process information

| | Company A | Company B | Company C | Company D |
|---------------------------|--|--|--|--------------------------------------|
| TPM | 1994 | 1998 | 2005 | 2006 |
| Consulting | IM&C – JIPM | Excellence Consulting | IM&C - JIPM | Loss Prevention |
| TPM Initiative | Management (Top-Down) | Management (Top-Down) | Management (Top-Down) | Headquarters USA |
| Original Access Way | Visit to Japan | Visit to other national companies | Visit to Japan and South Korea | Training USA |
| TPM Coordination | Yes | Yes | Yes | No |
| Visits to other companies | Yes | Yes | Yes | --- |
| <i>Kick Off</i> | By the management to all the factory with explanatory primer | By the management to all the factory with explanatory primer | By the management to all the factory with explanatory primer | By the headquarter (USA) to managers |
| TPM areas | Industrial | Industrial | Industrial | Maintenance |

The use of internal resources, namely multipliers, is characterized unanimously in the analyzed units and the use of primers and gifts expresses each company’s efforts to disseminate the concepts to all organizational levels. Concerning the metrics used, all companies focus on global performance of their resources and indicators related to maintenance performance.

Table 4. Structuring of TPM activities: forms of knowledge absorption, replication, Adaptation and used metrics.

| | Company A | Company B | Company C | Company D |
|------------------------------------|---|---|---|-------------------------|
| Way of knowledge absorption | Training, Consulting, Visits to other companies | Training, Consulting, Visits to other companies | Training, Consulting, Visits to other companies | Training Consulting |
| Knowledge replication | Multipliers preparation | Multipliers preparation | Multipliers preparation | Multipliers preparation |
| Organizational culture adaptations | Gifts, cleaning cloths, explanatory primer | Gifts, t-shirts, explanatory primer | Gifts, key-chains, explanatory primer | Explanatory primer |
| Main Metrics | OEE - MTBF – MTTR – Costs | OEE – MTBF – MTTR | OEE – MTBF – MTTR | OEE - MTBF |

Note: OEE: Overall Equipment Effectiveness; MTBF: Mean Time Between failures; MTTR: Mean Time to Repair

Table 5. TPM activities structure: success and failure factors

| | Company A | Company B | Company C | Company D |
|---------------------|---|--|---|--|
| TPM Success factors | <ul style="list-style-type: none"> * High Administration commitment * Methodological Rigor * Communication * Training | <ul style="list-style-type: none"> * Connection with the Program of Result Improvement * Financial incentive * Participation in all levels * Hierarchy involvement | <ul style="list-style-type: none"> *Leadership *Good operational results *Motivation | <ul style="list-style-type: none"> *Cooperate demand *good preliminary results |

| | | | | | |
|---------------------|-------------------|---|---|---|---|
| | Operational Level | * Willingness * Managers signaling TPM's importance * Belief that it can work | *Trainings *Goals clarity * Strategy directive unfolding *Transparency *Communication | *Personal development *Good practices recognition *Communication | *Better organization *5 S *Corrective action time reduction *Operators' knowledge increase *Better relationship |
| TPM Failure factors | Managerial Level | * Lack of belief * Lack of understanding from the high administration * Methodology complexity | *Lack of team involvement *Disbelief | *Some levels resistance *Need of more training | * Some level resistance * Production lack of time |
| | Operational Level | * Intermediary level lack of demands *Lack of <i>feed back</i> * <i>Lack of perseverance</i> * <i>Lack of motivation</i> | * Lack of service quality * Need of more visits to other companies | *Need of more training * Need of better TPM knowledge * Knowledge other pillars | * Need of better TPM knowledge * Littler training * Lack of production involvement |

TPM's success factors, according to the managerial level, are associated to the high administration commitment (Ireland and Dale, 2006); to the team involvement and results achieved.

TPM's success factors, according to the managerial level, are associated to the high administration commitment [18]; to the team involvement and results achieved. Concerning the operational level, it is possible to observe that the possibility of personal development; work environment and communication improvement; information and goals transparency are the main indicators of the program's success.

As for the factors that can lead TPM to failure among managers, it is possible to observe that the resistance in intermediary levels is prominent in all analyzed units. Among the operational level, lack of training is considered the prominent factor to lead the program to failure.

4.1 Applied questionnaire quantitative analysis

In this section, the result of variance analysis is presented based on Tukey's test (T-Test), exploring various data obtained during the field research.

4.1.1 Operational group questionnaire quantitative analysis (operators/autonomous maintenance group members/mechanical technicians)

In the industry factor, Company B presents the best result for the variable "Knowledge" 4.55 in Table 1). This result is not significantly different from Company C, but it is better than Company A and Company D results. The results of Company C are not very different from Company D, which has the worst result concerning knowledge. Factor "time" is not important because there is no difference among means for all variables.

Table 1. Statistical analysis of questionnaire responses – Part 1.

| | | | Knowledge | | Quality | | Breakdown | | Safety | | Stage Evaluation | |
|--------------------------|------------------------|-----------|-----------|----|---------|---|-----------|----|--------|----|------------------|----|
| | GENERAL AVERAGE | | 3.99 | | 4.10 | | 4.23 | | 4.47 | | 4.51 | |
| | CV (%) | | 18.89 | | 16.58 | | 19.29 | | 18.44 | | 15.63 | |
| | | DF | | | | | | | | | | |
| VARIANCE ANALYSIS | MS INDUSTRY | 3 | 20.8876 | * | 20.6682 | * | 9.3315 | * | 3.0439 | * | 2.6272 | * |
| | MS TIME | 4 | 1.0226 | ns | 1.1467 | * | 1.2922 | ns | 1.2942 | ns | 1.0539 | ns |
| | MS EDUCATION | 2 | 1.3816 | ns | 1.8077 | * | 0.5952 | ns | 0.7822 | ns | 0.1473 | ns |
| | MS SECTOR | 2 | 9.8892 | * | 8.4574 | * | 4.5142 | * | 1.7867 | ns | 1.0779 | ns |

| | | | | | | | | | | | | |
|--------------------------|----------------|----------|---------|----|---------|---|---------|---|--------|--------|--------|---|
| | MS AUTON GROUP | 1 | 23.6596 | * | 28.4290 | * | 12.7637 | * | 2.1487 | ns | 6.1184 | * |
| | MS RESIDUAL | 213 | 0.5682 | | 0.4615 | | 0.6661 | | 0.6793 | | 0.4968 | |
| MEANS | | N | | | | | | | | | | |
| INDUSTRY | COMPANY A | 67 | 4.06 | B | 4.22 | A | 4.33 | A | 4.67 | A | 4.55 | A |
| | COMPANY D | 49 | 3.04 | C | 3.12 | B | 3.57 | B | 4.14 | B | 4.16 | B |
| | COMPANY C | 68 | 4.26 | AB | 4.41 | A | 4.44 | A | 4.41 | A B | 4.66 | A |
| | COMPANY B | 42 | 4.55 | A | 4.52 | A | 4.50 | A | 4.62 | A | 4.60 | A |
| TIME | 1 | 23 | 3.78 | A | 3.87 | A | 4.13 | A | 4.48 | A | 4.61 | A |
| | 2 | 17 | 4.24 | A | 4.18 | A | 4.06 | A | 4.53 | A | 4.65 | A |
| | 3 | 19 | 3.74 | A | 3.95 | A | 4.16 | A | 4.21 | A | 4.11 | A |
| | 4 | 21 | 3.86 | A | 3.81 | A | 3.86 | A | 4.10 | A | 4.38 | A |
| | 5 | 146 | 4.05 | A | 4.18 | A | 4.33 | A | 4.55 | A | 4.55 | A |
| EDUCATION | 1 | 32 | 4.25 | A | 4.41 | A | 4.41 | A | 4.63 | A | 4.53 | A |
| | 2 | 140 | 3.97 | A | 4.06 | B | 4.19 | A | 4.41 | A | 4.53 | A |
| | 3 | 54 | 3.89 | A | 4.02 | B | 4.22 | A | 4.54 | A | 4.44 | A |
| SECTOR | 1 | 118 | 4.21 | A | 4.32 | A | 4.40 | A | 4.56 | A | 4.60 | A |
| | 2 | 11 | 4.55 | A | 4.45 | A | 4.45 | A | 4.73 | A | 4.45 | A |
| | 4 | 97 | 3.66 | B | 3.78 | B | 4.00 | B | 4.33 | A | 4.40 | A |
| AUTONOMO US GROUP | S | 136 | 3.73 | B | 3.81 | B | 4.04 | B | 4.39 | A | 4.38 | B |
| | N | 90 | 4.39 | A | 4.53 | A | 4.52 | A | 4.59 | A | 4.71 | A |

The same analysis is done for “Education”, “Sector” and “Autonomous Group”. It is worth noticing that because there were only two levels of autonomous groups (S and N), means were compared directly with the result presented by the test F, without the contest of Tukey’s test, that in this situation does not have the same quality.

Table 2. Statistical analysis of questionnaire responses – Part 2.

| | | | Environ ment | | Perfor mance | | Relat superior | | Relat colleague s | | Productiv | |
|--------------------------|------------------------|-----------|-----------------|--------|-----------------|----|-------------------|--------|-------------------------|----|-----------|----|
| | GENERAL AVERAGE | | 4.47 | | 4.53 | | 4.06 | | 4.07 | | 4.27 | |
| | CV (%) | | 16.78 | | 14.01 | | 17.99 | | 19.02 | | 19.54 | |
| | | DF | | | | | | | | | | |
| VARIANCE ANALYSIS | MS INDUSTRY | 3 | 4.3358 | * | 1.0808 | * | 10.6493 | * | 7.7211 | * | 5.8659 | * |
| | MS TIME | 4 | 0.7588 | n s | 0.1340 | ns | 0.0201 | n s | 1.0367 | ns | 0.5537 | ns |
| | MS EDUCATION | 2 | 2.0189 | * | 0.4878 | ns | 1.8000 | * | 1.7459 | ns | 0.4250 | ns |
| | MS SECTOR | 2 | 3.1135 | * | 1.4529 | * | 9.0258 | * | 5.5377 | * | 4.4335 | * |
| | MS AUTON GROUP | 1 | 0.2649 | n s | 4.8531 | * | 31.6845 | * | 17.3210 | * | 14.5858 | * |
| | MS RESIDUAL | 213 | 0.5620 | | 0.4027 | | 0.5341 | | 0.5994 | | 0.6946 | |
| MEANS | | N | | | | | | | | | | |
| | COMPANY A | 67 | 4.72 | A | 4.54 | AB | 4.09 | B | 4.15 | A | 4.15 | B |
| INDUSTRY | COMPANY D | 49 | 4.12 | C | 4.33 | B | 3.39 | C | 3.49 | B | 3.86 | B |
| | COMPANY C | 68 | 4.60 | A B | 4.57 | AB | 4.41 | A | 4.37 | A | 4.43 | AB |
| | COMPANY B | 42 | 4.26 | B C | 4.69 | A | 4.24 | A B | 4.14 | A | 4.67 | A |
| TIME | 1 | 23 | 4.57 | A | 4.57 | A | 4.09 | A | 4.13 | A | 4.22 | A |
| | 2 | 17 | 4.47 | A | 4.65 | A | 4.12 | A | 4.29 | A | 4.47 | A |
| | 3 | 19 | 4.26 | A | 4.58 | A | 4.05 | A | 3.84 | A | 4.00 | A |
| | 4 | 21 | 4.19 | A | 4.43 | A | 4.05 | A | 3.76 | A | 4.33 | A |
| | 5 | 146 | 4.52 | A | 4.52 | A | 4.05 | A | 4.11 | A | 4.27 | A |

| | | | | | | | | | | | | |
|----------------------------------|---|-----|------|--------|------|----|------|--------|------|----|------|---|
| | 1 | 32 | 4.69 | A | 4.50 | A | 4.28 | A | 4.19 | A | 4.41 | A |
| EDUCATION | 2 | 140 | 4.50 | A B | 4.49 | A | 4.09 | A B | 4.13 | A | 4.26 | A |
| | 3 | 54 | 4.26 | B | 4.65 | A | 3.87 | B | 3.85 | A | 4.20 | A |
| | 1 | 118 | 4.63 | A | 4.64 | A | 4.33 | A | 4.28 | A | 4.40 | A |
| SECTOR | 2 | 11 | 4.36 | A B | 4.55 | AB | 3.91 | A B | 4.00 | AB | 4.73 | A |
| | 4 | 97 | 4.29 | B | 4.40 | B | 3.75 | B | 3.82 | B | 4.05 | B |
| AUTONOMO US GROUP | S | 136 | 4.44 | A | 4.41 | B | 3.76 | B | 3.85 | B | 4.06 | B |
| | N | 90 | 4.51 | A | 4.71 | A | 4.52 | A | 4.41 | A | 4.58 | A |

Note: One of the questionnaires was removed: Company B, time 5, education 3, sector 5 and autonomous group S. This was the only one referring to Sector 5. All other questionnaires belonged to sectors 1,2 and 4. There was, therefore, none from sector 3.

Statistics analysis of data obtained from the operational level allowed the observation that the smaller variability among answers happened in variable “Performance”, which may assure that the respondent operators’ visions strongly relates TPM to a productivity elevating program, in all analyzed units.

Analyzing variable “Stage Evaluation”, it is possible to notice that there is a clear vision that TPM is a long term program and that, according to the worker’s view, it needs to be monitored periodically by managers, in a stage evaluation systematic that allows measurement along with the implementation time, the recognition of the good practices and processes related to TPM.

It is also possible to observe that the operational base associates TPM to the existence of a clean, pleasant, organized and consequently safe work environment (variables Safety and Environment). This reinforces the thesis that the worker’s direct participation and involvement in the cleaning, lubrication and inspection of equipment – which constitutes the basis of the activities in the Autonomous Maintenance pillar – is what guarantees TPM’s success, as defined by Najakima [4] in the scope and concept of this program.

Concerning the worker’s level of knowledge (variable Knowledge), it is clear that its magnifying is associated with the way each unit developed the activities related to training and capacitating the people in the TPM program.

Company D, for example, showed distinctive means from the others, reinforcing what was clear and evident during the visit to the company: there was not a wide dissemination of TPM concept. This is probably due to the fact that the implementation decision had been defined more recently by the high administration and no significant training event had been given to the workers to mark TPM activities kickoff.

Concerning TPM activities influence on the workers relationship, there was an elevated variability, with mean completely distinctive from Company D, in relation to those in the autonomous groups and those who were not. It is possible to assume that the reduction of equipment breakdown (variable Breakdown) is directly associated with the results and with the program implementation time. Productivity showed a more representative variability, also associated with the belief in TPM results.

Education, therefore, influences and is statistically significant to the matters related to work quantity and quality, physical environment and relationship to superiors. This is probably due to the fact that TPM, when disseminated to the operational environment and with the performance of the AM pillar stage 1 activities (that deal with the “5S” improvement), induces a physical change in the place, which from then on has a cleaner, more pleasant and organized layout.

The first stage of the program development and the Autonomous Maintenance Pillar, stages 1 to 3, preconize the recovery of the basic conditions of the equipment and induce the need of the worker’s effort in restoring basic conditions of the equipment and also the working environment. The improvement in the relationship with the superiors, statistically significant, is connected to TPM activities development, which demands team work and closer relationship between the leaders who play the role of the program’s facilitators and multipliers with their learners. Results also show that belonging or not to the Autonomous Groups magnify and prove the perception of the workers’ answers concerning TPM analyzed effects.

4.1.3 Quantitative analysis of the questionnaires applied to the managerial group (Directors/Managers and TPM Coordinators)

Based on the criteria of significant differences of means – Tukey and T-Test, the answers of managers from the four units in this work were also analyzed. Table 3 presents statistically analyzed data. There is no significant difference among all the companies concerning these five variables studied. Although factor “Industry” is significant in the variable “Guarantees Competitiveness” (1.8056*), Tukey’s mean test could not detect significant differences. The mean test is valid and the conclusion is drawn by the lack of difference.

The fact that there is no significant difference among the analyzed units concerning the studied variables, evidences the managers' perception that TPM is a program that guarantees competitiveness and creates greater personnel involvement with productivity and quality matters. It is also clear that managers perceive less involvement of the administrative areas with TPM activities, which proves this program starts always through the factory and gradually reaches managerial activities and operational support.

Table 3. Variance analysis of the managerial group questionnaire response

| | | | TPM | | Guarantees Competitivity | | Personnel better involvement | | Administration involvement | |
|-------------------|-----------------|----|--------|---|--------------------------|---|------------------------------|---|----------------------------|---|
| | General Average | | 3.8 | | 45 | | 4.65 | | 3.3 | |
| | CV (%) | | 15.19 | | 1530 | | 11.30 | | 33.60 | |
| | | DF | | | | | | | | |
| Variance Analysis | MS industry | 3 | 0.6222 | | 1.8056 | * | 0.0444 | | 3.5111 | |
| | MS residual | 16 | 0.3333 | | 0.4740 | | 0.2760 | | 1.2292 | |
| Means | | | | | | | | | | |
| Industry | Company A | 4 | 4.00 | a | 5.00 | a | 4.50 | a | 200 | a |
| | Company D | 6 | 4.00 | a | 5.00 | a | 4.67 | a | 3.83 | a |
| | Company C | 4 | 4.00 | a | 3.75 | a | 4.75 | a | 3.00 | a |
| | Company B | 6 | 3.33 | a | 4.17 | a | 4.67 | a | 3.83 | a |

V. CONCLUSION

Based on the found results in the analyzed Brazilian companies, it is possible to conclude that:

- TPM implementation process has gone through the adoption of a series of practices by the organizations, which involved all the organizational structure concerning adaptations to the organizational reality of each company;
- Methodology concepts absorption was directly connected to the use of TPM pillar concepts, following certain logic in such pillar's stage implementation and in the relation of the existing activities between them;
- Companies advanced in the quantity of TPM activities along the implementation time, i.e., culture was disseminated through other areas as each stage was effectively implanted;
- The decision of initiating TPM originated from the high administration influenced by *benchmarking* achievement abroad, visiting practicing companies in Asian countries (Japan and Korea);
- To know TPM activities implementation ways, companies used external consulting and also benchmarking process with other practicing national companies;
- TPM implementation process is very fragmented and develops only according to punctual training received;
- Internal training for TPM concept dissemination formed multipliers who reproduced the same information to companies colleagues;
- Low education in the operational level was reason for hindrance for more complex training about TPM techniques;
- There is strong resistance in intermediary levels concerning the implementation of TPM activities;
- There was improvement in the relationship and communication between superiors and subordinates after TPM activities implementation;
- There is strong association between TPM and the aspects related to cleaning and organization in the productive environment (5 S);
- TPM implementation started with the activities of the autonomous maintenance pillar;
- Management in sight, using metric boards and performance indicators is strongly associated to TPM.

Because of the study's exploratory nature, it is adequate to the deep investigation of the approached themes, but it is subject to limitations. TPM different stages of implementation in the analyzed companies, due to different periods of adoption, are presented as one of the limitations in this study. Conclusions are restricting to the cases studied, although relationships about the different aspects of the program can be done.

REFERENCES

- [1]. S.P. Robins, *Organizational Behavior*. (São Paulo: Pearson Prentice Hall, 2005).
- [2]. M.P. Caldas and T. Wood Jr., Adopting imported managerial expertise in developing countries: the Brazilian experience. *Academy of Management Perspectives*, 16 (2), 2002, 18-32.
- [3]. JIPM. Japan Institute of Plant Maintenance. *Criteria for Excellence TPM Awards*. (Tóquio: JIPM, 2002).
- [4]. S. Nakajima, *La Maintenance Productive Totale*. (Paris: Afnor, 1989).
- [5]. K.E. Mckone, R.G. Schroeder and K.O. Cua, Total productive maintenance: a contextual view, *Journal of Operations Management*, 17 (1), 1999, 123-144.
- [6]. K.E. Mckone, R.G. Schroeder and K.O. Cua, The impact of total productive maintenance practices on manufacturing performance. *Journal of Operations Management*, 19 (1), 2001, 39-58.
- [7]. M. Tajiri and F. Gotoh, *Autonomous maintenance in seven steps. Implementing TPM on the shop floor* (Portland: Productivity Press, 1999).
- [8]. D. Seth and D. Tripathi, A critical study of TQM and TPM approaches on business performance of Indian manufacturing industry. *Total Quality Management*, 17 (7), 2006, 811-824.
- [9]. K. Shirose, *TPM: New implementation program in fabrication and assembly industries* (Tokio, JIPM – Japan Institute of Plant Maintenance, 1997).
- [10]. J.K. Liker, *The Toyota Way: 14 management principles* (McGraw-Hill: London, 2004).
- [11]. C.J. Robinson and A.P. Ginder, *Implementing TPM: the North American experience* (Portland: Edwards Brothers, 1995).
- [12]. H. Ribeiro, *Total Productive Maintenance*. (São Paulo: EPSE, 2004).
- [13]. E.H. Hartmann, *Successfully Installing TPM in a Non-Japanese Plant: Total Productive Maintenance* (TPM Press Inc., Pittsburg, PA: 1999).
- [14]. K. Cua, K.E. Mckone and R.G. Schroeder, Relationships between implementation of TQM, JIT and TPM and manufacturing performance. *Journal of Operations Management*, 19 (1), 2001, 675-694.
- [15]. M.P. Marder, *Research Methods for Science*. (Cambridge, UK: Cambridge University Press, 2011).
- [16]. A.C. Gil, *How to elaborate research projects* (São Paulo, SP: Atlas, 2002).
- [17]. R.K. Yin, *Case Study: planning and method* (Porto Alegre, RS: Bookmam, 2005).
- [18]. F. Ireland and B.G. Dale, Total productive maintenance: criteria for success. *International Journal of Productivity and Quality Management*, 1 (3), 2006, p.