Management and operations maintenance for a water treatment and supply company

Abstract

This paper intends to highlight the importance of the maintenance activity for all kind of companies in general and for the water treatment companies in particular. To attain this objective a literature review on the evolution of the maintenance concept, the relation between the production function and the Total Productive Maintenance (TPM) and the factors that influence the success of TPM is performed.

To demonstrate the contribution of the maintenance activity for the improvement of the performance of companies especially for the water treatment companies a case study of a Portuguese company belonging to the water treatment sector is performed. The case study company is considered important for the water treatment sector since it has an annual capacity of treatment and distribution of 41 million m^3 of drinking water to approximately 438,000 inhabitants spread over a geographic area that represents 15% of the Portuguese territory. Thus, the analysis of the case study company, named as Water Company, aims to demonstrate the importance of the implementation of an adequate management and deployment of appropriate maintenance activities, mainly the Total Productive Maintenance (TPM), which seek to promote organisational synergies, corporate sustainability and success in the investment plan currently in force in this Portuguese sector.

Keywords: Management; Operations Maintenance; Environmental Monitoring; Water Treatment; Water Supply

1. Introduction

Currently, the production or processing companies define their business strategies and competitive priorities based on several factors related to their production systems, such as productivity, flexibility and quality, aiming for the reduction or elimination of waste. As a result, maintenance plays a crucial role in ensuring the availability and reliability of facilities (Muchiri et al., 2011, Karamouzian et al.,2014).In recent years the maintenance has being recognised as contributing to company profitability and competitiveness (Sardana and Sinha, 2011; Singh et al., 2012; Ingwald and Basim Al-Najjar, 2012; Eslami et al., 2014). Increasingly, companies are made aware of the critical need to implement policies to maintain appropriate facilities and equipment [Alsyouf, 2009; Sharma et al.,2012]. Ahuja (2011) presents a literature review concerning maintenance practices in manufacturing organisations. Without proper maintenance of equipment installed, any plant will lose competitiveness in today's markets, which require low-cost products with high quality and short delivery times (Alsyouf, 2009). Studies conducted (Alsyouf, 2009) have examined the waste of energy in American industry from damage or improper maintenance of networks and equipment for

compressed air, resulting in an annual cost of 3.2 billion dollars for Enterprise. Thus, proper maintenance practices can contribute to overall company performance through impact on the quality, efficiency and effectiveness of operations. These practices can contribute to the increased productivity and competitiveness of an organisation, which will prove profitable in the long term (Alsyouf, 2009). Accordingly, shareholders and the company customers may be affected positively, as shown in Fig.1.

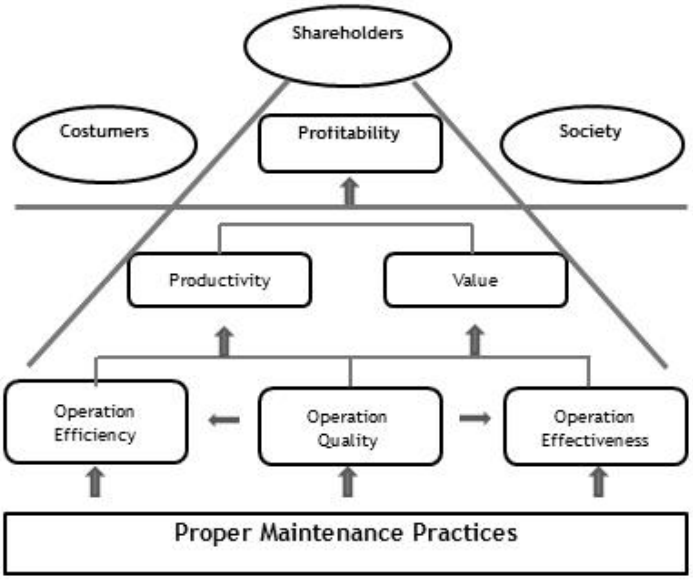

Fig.1. Impact of proper maintenance practices

Although the global economic crisis has forced companies to reduce costs within their business, the development of policies in the area of maintenance has proved to be an important contribution to appropriate maintenance actions, to guarantee efficiency in terms of the quality, availability and serviceability of the facility. For this reason, it is evident that the service concept within organisations has evolved significantly over time (Faccio et al., 2012). In fact, the planning and execution of appropriate maintenance actions reveals itself as an objective for Enterprise, aimed at improving the availability and reliability of production systems, with the intention of maximising productivity, product quality and safety of operations to minimise the total cost of maintenance.

Being so this paper aims to enhance the importance of the maintenance activity for improving the performance of the companies.

This paper is organized in the following way: after the introduction a literature review on the evolution of the maintenance concept, the Total Productive Maintenance concept, the function and maintenance in the TPM context, factors that influence the success of TPM is present. Then the methodology used in this research is described and the case study is performed. Finally a conclusion is drawn.

2. Maintenance in the present

With the advent of more complex systems and autonomous production, it is found that unexpected breakdowns have led to increased cost in manufacturing processes. About a third of the overall maintenance costs have been wasted due to improper and in some cases unnecessary maintenance activity was planned and executed (Xia et al., 2012). There is therefore a need to develop an efficient maintenance activity, which strategically creates a structure that allows the maintenance of the equipment and of the system by keeping the process under optimal conditions of operation. Over time

and with use of equipment, these will be degraded however. Without taking proper conservation, the breakdown will inevitably lead to failure and corresponding downtime production, which will result in injury to the organisations. Preventive maintenance, properly planned and executed, proves to be more efficient and positive than corrective maintenance, with regard not only to the costs of the action itself, but also the productive activity of the business. Furthermore, in the current economic crisis, where there is a retraction in the decision of new investments by companies, the function of preventive maintenance plays an important role in the conservation of existing equipment, allowing the operability and reliability of the same for a longer period. In this respect, increasing the downtime of equipment, the problems of quality, loss of production speed, safety hazards and environmental pollution become obvious results. All these results have the potential to affect adversely the operating cost, profitability, customer satisfaction and productivity among other consequences. To ensure that a production facility operates in ideal conditions, complying with the stipulated cost of production and expected profitability, the maintenance sector has to take decisions about the maintenance strategies required for the objectives of the organisation to be achieved. Thus, the strategy and objectives of the service must not be determined in isolation, but rather derived from factors such as: company policy with regard to production, as well as other requirements and restrictions of private organisations defined in [Muchiri et al., 2011; Dilanthi, 2013]. According to Muchiri et al. (2011), the objectives of maintenance in any organisation can be summarised into five sections, as shown in Fig 2.

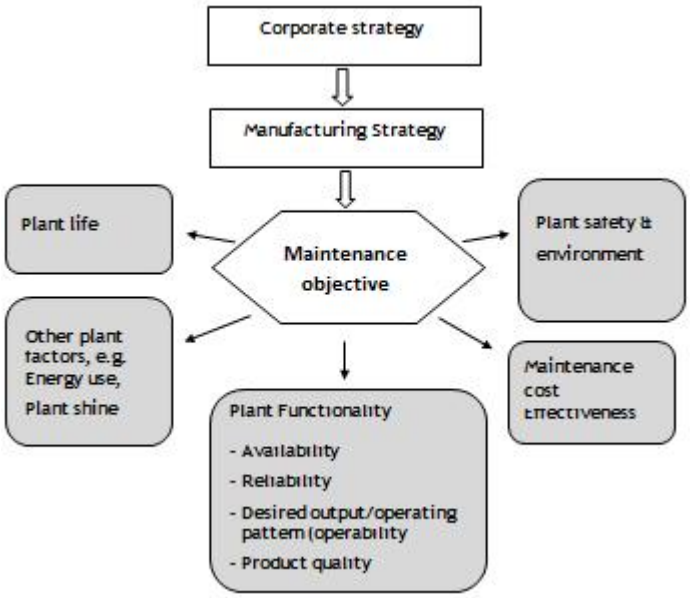

Fig.2. List of targets for industrial maintenance

2.1. The need to change the concept of maintenance

Companies in the past decades were confronted with a large number of changes at the level of concepts and management approaches, products, process technologies, customer expectations and attitudes of suppliers. These changes were essentially derived from a competitive factor, which is the intention of any company (Ahuja and Khamba, 2008; Jeon, 2011; Golmakani and Namazi, 2014). Ahuja (2011) presents a literature review on maintenance practices in manufacturing organisations. The current globalisation of markets led to increased competition, as well as increased demand from customers (Ahuja and Khamba, 2008). According to Gotoh, Hipkin and Cock (Ahuja and Khamba, 2008; Ahuja and Khamba, 2008b), continuous improvement in production operations, by itself, does

not guarantee the competitiveness or sustained profitability, or even survival of organisations. Companies that face the challenges posed by the current competitive environment will promote initiatives to improve performance in all aspects of operations, as a way to promote their competitiveness (Muchiri et al., 2011). In recent years, the development of technologies and philosophies of production has been altered in part by the adoption of new production concepts, such as Lean Manufacturing, JIT, TQM and Six-Sigma (Ahuja and Khamba, 2008; Ahuja, 2011; Singh and Ahuja, 2012; Sugumaran et al., 2014). However, in some cases the benefits resulting from the adoption of these philosophies have proved somewhat limited, due to the lack of reliability of production equipment (Ahuja and Khamba, 2008; Ahuja, 2011a). To this end, the effectiveness of maintenance has to be improved (Kenneth et al., 2013; Wang, 2010). As a result of inadequate insight into maintenance, it was found that companies pledged their organisational competitiveness, reducing performance and reliability through the rapid deterioration of facilities and production equipment, which resulted in reduced availability of equipment, such as the effect of excessive downtime. According to (Ahuja and Khamba, 2008), for organisations to be successful, they must implement strategies to maintain efficient and effective production strategies. Also, the author argues, the vision of the organisations in terms of maintenance, as part of industrial success, will allow companies large amounts of spare time, money and useful resources to achieve reliability, availability and performance in industry. The awareness of large companies worldwide of the importance of the maintenance function within organisations, led them to adopt strategies and philosophies of efficient maintenance, such as philosophy CBM – Condition Based Maintenance – RCM – Reliability Centred Maintenance – and TPM – Total Productive Maintenance – at the expense of traditional approaches to reactive maintenance (Ahuja and Khamba, 2008; Jeon et al., 2011).

3. The Total Productive Maintenance (TPM) concept

Since the TPM philosophy has been widely recognised and emphasised in the literature as a strategy to improve productivity performance, the approach presented here does not intend to bring to the discussion the basis of TPM, but rather, to demonstrate in a practical context the benefits of its implementation, as well as establish some factors that may affect the expected results of its adoption. It has been argued (Ahuja and Khamba, 2008; Gupta and Garg, 2012; Ahuja, 2011b; Singh et al., 2012) that the TPM philosophy provides organisations that adopt it, a guide to transform their facilities, integrating culture, processes and technology, which increases the efficiency of the means of production. According to (Ahuja and Khamba, 2008; Gupta and Garg, 2012) and the JIPM – Japan Institute of Plant Maintenance – TPM philosophy is supported by eight pillars: i) autonomous maintenance, ii) planned maintenance, iii) specific improvements, iv) education and training, v) maintaining quality vi) monitoring and initial improvements, vii) administrative management and the total viii) health, safety and environmental monitoring. This methodology has emerged as a response to market demand to become extremely competitive, and has forced companies to rethink their attitude within organisational structure, with regard to the reduction or elimination of waste, demand for higher performance of facilities and equipment and reduced production stops, motivated by breakdowns or planned interventions (Gupta and Garg, 2012). According to Rodrigues and Hatakeyama (2006), the implementation of TPM philosophy aims to eliminate six types of waste resulting from the operation of the equipment, which negatively influence the performance of the production process, as shown in Fig 3.

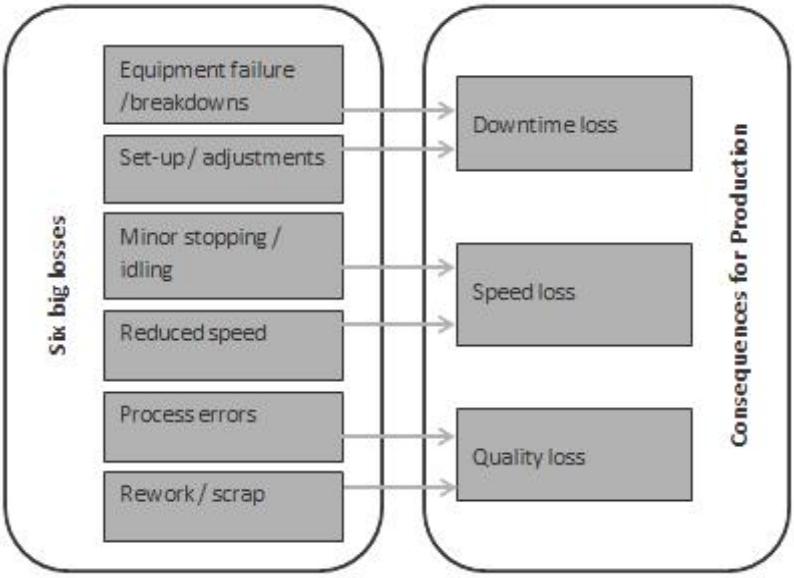

Fig.3. Operational objective of TPM

3.1. The production function and maintenance in the TPM context

Sometimes, within business, there exists an adversarial relationship between actors in the production and maintenance resulting from the lack of definition of particular competencies. Thus, considering that the successful implementation of TPM depends largely on the commitment and motivation of human assets, it appears extremely important to have a clear and correct definition of responsibilities of each sector in the process of maintenance, so that the synergy created can deliver the results expected from the implementation of this methodology. It is suggested by (Ahuja and Khamba, 2008; Rodrigues and Hatakeyama, 2006; Tsao et al., 2012; Singh et al., 2012; Muthukumar et al., 2012) that the TPM promotes a synergistic relationship between all organisational functions, especially between production and maintenance. This methodology aims at continuous improvement of product quality and operational efficiency and ensuring organisational capacity. From the point of view of Rodrigues and Hatakeyama (2006) and Tsao et al. (2012), no matter how much the companies are equipped with technologically advanced equipment and techniques, there are always productive operators and maintenance technicians affecting the positive or negative performance of a factory. Thus, operators and maintenance technicians reached a mutual understanding of their roles and responsibilities with regard to the conservation of productive equipment (Dhouib et al., 2012). In fact, all sectors that have a direct participation in and responsibility for the production equipment must cooperate and understand their specific functions mutually (Dhouib et al., 2012). This cooperative effort will allow the sector to maintain its focus on synergies requiring specific techniques, as well as direct efforts so that work can be aimed at the optimisation of equipment with regard to increased capacity production and quality of processed products. Considering the above, we will then present the responsibilities of production operators and maintenance technicians within the maintenance of equipment in the context of the TPM methodology:

Responsibilities of the operation;

i) Keep the basic operating conditions of the equipment, with the implementation of autonomous maintenance, cleaning tasks, lubrication, visual inspections and proper operation;

ii) Identify the early deterioration of the equipment inspection, mainly from signals which could indicate future stops and degradation of quality resulting from operation;

iii) Improve the productive skills, such as equipment operation, through small adjustments, avoiding compromising reliability and operability of the equipment;
iv) Analyse the permanent characteristics of the processed product, comparing them with the standard features preset.

Maintenance responsibility;

i) Provide technical support for activities of daily maintenance, for those who are in charge of the operation;
ii) Restore the equipment to its operating condition, meeting the demands of operating in an accurate and timely manner;
iii) Clarify the rules of operation of the equipment, resulting from the initial project, and promote improvement projects and adjustments to increase production capacity;
iv) Improve the skills of maintain the equipment, by performing check-ups, inspections, reviews and continuous monitoring of production conditions.

Fig. 4 represents the interaction and responsibility between the two sectors in ensuring the effectiveness of production equipment maintenance, considering the definition of the specific duties and functions, as suggested by the TPM methodology.

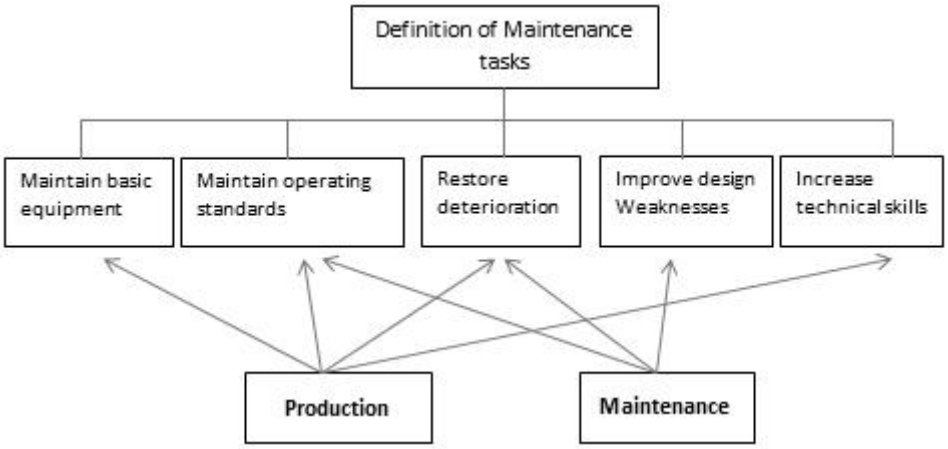

Fig.4. Sector's contribution to the maintenance and operation maintenance activities

3.2. Factors that influence the success of TPM

According to Dhouib et al. (2012), some of the problems that may lead to failure of the implementation of TPM include: cultural resistance to change, partial implementation of the TPM, overoptimistic expectations, lack of well-defined routines to achieve the objectives of this methodology, lack of training and education, lack of organisational communication and a wrong way of implementing TPM, without the necessary framework of the particular practices of the company concerned. As for Dhouib et al. (2012) and Ireland and Dale (2001), one of the main factors leading to the failure of TPM relates to the lack of capacity that organisations have to overcome. This fact leads to the actors' interventional reluctance to change routines and habits in their daily tasks. Considering production operators (Dhouib et al., 2012); Ireland and Dale, 2001) argue that this reluctance is due in large part to the fear that the implementation of TPM practices will increase their workload. As for maintenance technicians, there is a sense of insecurity about maintaining their job. The authors also report potential barriers that often affect the implementation of TPM, resulting from the inability of organisations to coordinate human resource management policies and technology. Although in recent years many companies worldwide have attempted to implement the practices of TPM, less than 10%

of them were successful. Thus, the author believes that the basis for achieving the fullness of the objectives of TPM is the change in culture and behaviour of all employees, including operators, engineers, maintenance and proper management of the organisation. Considering the above, we conclude that the success of this practice is closely and directly dependent on good human management. According to (Ireland and Dale, 2001), the lack of commitment of managers to these practices leads to the ruin of an entire structure pre-formulated and established. Below is a summary of the main factors that may negatively influence the implementation of the practices described by the TPM;

i) Growing need for operators to increase production capacity;
ii) Lack of time for the autonomous maintenance;
iii) Operation of multiple machines at the same time by the same operator;
iv) Mentality of operators – that work is production and not maintenance;
v) Rapid deployment of TPM without the structural consolidation of practices;
vi) Lack of training and learning, as regards not only the technical but also the management bodies;
vii) Lack of monitoring of the implementation and progress of the programme;
viii) Objectives not achieved without clearance of the causes that led to that situation;
ix) Lack of commitment on the part of supervisors and senior chiefs;
x) Cut funding for the implementation of TPM practices without clear justification for those responsible for implementation.

Within organisations apparently, pressure and workload can induce the perception of an increase in productivity. However, in a short time, this will prove to be negative. In such a scenario, increase in production costs with a growing need for rework, as well as equipment malfunction will soon arise [18]. This work overload will result in the lack of participation of operators in the TPM, limiting them to the production function, and leading inevitably to the background the associated performing maintenance tasks. When this happens, not only in the medium term will the organisation suffer the consequences, but also in the short term the operator will feel demotivated and undervalued in the office since from the beginning of the implementation of TPM, it was endowed with professional valences that allowed him to act at the level of small adjustments, repairs and preventative maintenance. Another demotivating factor, which is sure to condition the expected results with the implementation of TPM, is largely related to the undervaluation of ideas, suggestions, or even non-participation of operators in the process of optimisation and proposals for the improvement of equipment. In this scenario, the operators will take a stance of indifference towards the equipment and organisation, limiting themselves to quantifiable target production. Thus, companies will lose an important channel of information that could lead to improvement. In addition to the above factors, according to (Ahuja and Khamba, 2008c), we can also highlight other factors that negatively influence the success of TPM:

i) Problems resulting from the acquisition of spare parts or materials, hindering the effectiveness of planned maintenance;
ii) Improper sizing of the maintenance team responsible for the activities' scheduled maintenance;
iii) Frequent changes in the schedule of availability of machines for interventions;
iv) Failure of systematic maintenance planning;
v) Lack of interest and lack of attitude of top management towards the practices of TPM;
vi) Lack of motivation of maintenance technicians, resulting from the execution of tasks, such that the operation should be performed.

In order to address the factors outlined above, it is essential to create a high interconnection between the various sectors of the organisation where everyone understands and believes in the benefits of the

implementation of TPM practices in general. Fig. 5 is an example of the practical importance of autonomous maintenance with the productive operator, and how this can work as a differentiating strategy for maintaining activity with benefits for the organisation.

The interaction and performance of the responsibilities of each of the agents in the process turns out to be the basis for the success of TPM. Any attempt otherwise, outside this global vision, will always result in a palliative to the practices of TPM. The amendments to the practices and initiatives of TPM must be anchored in organisations that adopt and should thus become an integral part of everyone's daily routine (Ahuja and Khamba, 2008c; Ahuja, 2011a, Ahuja, 2011b).

In other way, TPM is one of the maintenance strategies that aim to increase availability and reliability of production machines/equipment. The key to TPM success is the development of autonomous maintenance (AM). The AM refers to human capital development among operators supported by technicians and engineers to perform easy daily maintenance activities aside from planned maintenance. Min et al (2011) presents the implementation process of AM in a semiconductor company.

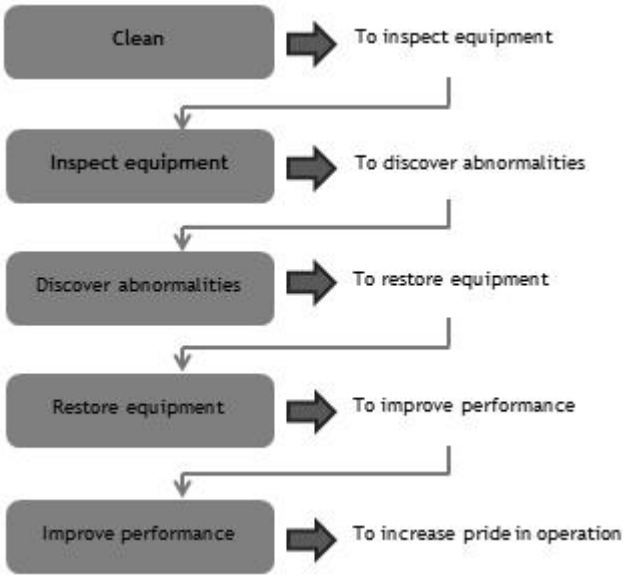

Fig.5. Influence of autonomous maintenance organizations

4 - Methodology

The main objective of this research is to enhance the importance of the maintenance activity for improving the performance of the companies in general and water treatment companies in particular. A qualitative methodology with a case study from the water treatment sector is used in this research.

According to Perry (1998) and Rowley (2002), a case study approach is adequate when the boundaries of a phenomenon are not only still unclear but there is also no control over behavioural events. In this research, the boundaries (maintenance activities which may influence the companies performance) are still relatively vague. To this end, one case study is analyzed to identify a set of maintenance activities and their influence on company's performance. The importance of case based research has been highlighted by a number of authors for operations (McCutcheon and Meredith, 1993; Stuart et al., 2002; Voss et al., 2002) and maintenance (Tsarouhas, 2007; Ahuja and Kumar, 2009; Chan et al., 2005).

Yin (2002) states that case studies can be exploratory, descriptive or explanatory. Because of restricted empirical evidence this research is exploratory in nature. In this paper a unique case study with a company from the water treatment sector is performed to attain the objectives of the research.

The main criterion used to choose the company to make part of the research was the convenience. (Patton, 2002). One of the researchers has a personal relationship with the CEO of the company which made possible accessing to some documents related to maintenance and performance indicators.

The triangulation was also used. Easterby-Smith *et al.* (1991) identified four different types of triangulation: data triangulation, investigator triangulation, methodological triangulation and theories triangulation. In this research the data triangulation is used since it was collected from different sources: the maintenance reports inside the company and interviews to the maintenance engineering.

5. CASE STUDY

In this section a case study approach is developed considering one company from the Portuguese water treatment sector. The aim of this section is to highlight the importance of the maintenance activities for improving the performance of companies.

5.1. Case study profile

The Water Company, owned by the Portuguese State Business, was created to meet the needs of the population in the region where it operates, in terms of regularity of treatment, supply and water quality. The treatment service and water supply, provided by the Water Company, with respect to a "high" service, i.e., the responsibility of action involves the caption of water, its treatment and delivery in municipal reservoirs. In comparison, service can be "low", i.e., the distribution to the final consumer, which is the responsibility of local municipalities. In this context, the whole system is responsible for providing service to about 30 municipalities, consisting of 36 water withdrawals in dams and reservoirs, 25 Water Treatment Plants (WTP), about 1350 kilometers of pipelines, 92 pumping stations and 93 reservoirs, which are distributed by geographic area of operation. To ensure this service, the Water Company is responsible for awarding contracts to promote the construction of infrastructure and installation of equipment, as well as to perform the operation, repair, renovation and maintenance of its facilities and associated equipment. Currently, the company has 224 employees, and the maintenance sector consists of 27 employees. The Water Company is guided in its conduct by an integrated management system (IMS) responsible for quality, environment and safety, having obtained the certificate in October 2009 (the relevant standards of ISO 9001:2008 for quality, ISO 14001:2004, OHSAS 18001:2007 for the environment and for health and safety at work). At present, the Water Company promotes the development of a strategic investment as a way of increasing service level in the region, aiming to provide the population covered with environmental protection and quality of life equivalent to its European partners. This objective has led to a classification of the existing infrastructure, in order to promote technically qualified exploration able to generate revenues to cover all costs of operation and the appropriate maintenance of facilities and equipment. From the above, it can be seen that water sector activity and maintenance of the company, this represents a critically important role, that the objectives can be achieved with this proposed plan. These objectives are summarised in the sustainability report of the sector, the efficiency of facilities, in compliance with public health, environmental protection, the extension of services to the population, in reducing tariffs to the consumer by optimising the operational management, in reducing or eliminating inefficiency costs, ensuring the preservation of the environment and increasing productivity and competitiveness.

5.2. Maintenance organisation

The maintenance sector of Water Company is structurally formed by the Directorate of Infrastructure, supported by two maintenance engineers. There are five and ten teams of maintenance technicians, each constituted of two technicians in the electromechanical area. Because of the wide geographic area covered by the company and dispersion of its production facilities, it appears that the leaders and maintenance technicians are uniformly distributed over a vast region. This decentralised distribution of human resources aims to promote greater proximity and technical teams responsible for maintaining the production facilities, and enabling a swifter response by them, especially in emergencies, as well as for the implementation of preventive maintenance actions and improvements, thereby promoting the efficient management and local planning of maintenance actions**.**

5.3 Maintenance planning

The success of any intervention depends on coordination, planning and effective programming, where cost, quality and time should be taken into account. According to Muchiri et al. (2011), the functions of management, planning and scheduling should include the following activities:

i) Set a work schedule of preventive maintenance;
ii) Attend to requests for changes and improvements of production equipment;
iii) Respond to outages and emergency services, with the necessary corrective action.

In the Water Company the responsibility for planning and scheduling of maintenance activities rests with the responsible maintenance. This planning is guided by the type of action to be taken, i.e., preventive maintenance actions, corrective work or improvement. In terms of preventive maintenance actions, the planning is carried out according to plan maintenance predefined for use in the company. This includes all the information, material and human resources needed to implement the intervention in question. As regards the planning of corrective maintenance work, it appears that after receipt of the work (PT), which is formulated by the responsible operation, maintenance starts the action planning, through the allocation of human and material resources for intervention. This is conditioned by the availability of skilled labour and materials required. Considering the improvement actions, it appears that planning and scheduling are developed in coordination with human resources and the internal materials of the company, as well as the use of external companies, which provide specialised services in the area in question. Usually resulting from the reduced criticality that such actions pose to the operation of the production facilities of the company, planning is done in a meticulous manner, involving long periods of time.

5.4. Organisation and structure maintenance policies

According to the author Alsyouf (2007) and Alsyouf (2009), the maintenance policies adopted by any company should match the most appropriate solution for the equipment or installation that is being considered by combining the various options to optimise the cost of its execution. Yet, according to the same authors in the adoption of (s) policy (s) maintenance should be considered the following aspects:

i) Reliability of equipment and its predictable rate of breakdowns;
ii) Maintainability of equipment relating to accessibility and ease of performing maintenance actions;
iii) Type of failure as a function of time due to resolution;
iv) Criticality of equipment in relation to its influence in terms of indirect costs resulting from the maintenance activity;

v) Consequence of failure in terms of human security, material and environment;
vi) Technical and economic viability, referring to the early detection of possible faults by monitoring operating variables;
vii) Technical and economic viability of alternative replacement or repair on site or in the workshop;
viii) Legal, as regards inspections of equipment;
ix) Evaluation of comparative economic benefit resulting from the various possible options to adopt maintenance.

The Water Company in the execution of corrective maintenance work and improvement, is the only responsibility by the maintenance sector, while the responsibility for the implementation of preventive maintenance actions is divided between the maintenance sector and the production sector/ operation. For this purpose, the company adopted in the organisation self-maintaining practice, supported in TPM, in combination with standard NFX60-010 created by the French Association for Standardisation (AFNOR). This suggests that the framework and typology of maintenance actions are divided into five levels. In such a way, responsibilities are assigned to employees to act in the process of maintenance, considering the degree of technical complexity of operations, the requisite qualification of performers and the technical resources involved in their interventions, as shown in Table 1.

Table 1 - Classification of specific maintenance activities by levels.

Maintenance levels according to AFNOR standard NFX60-010	Performance place	Responsible for implementation	Means for supporting the intervention
1st Level - Simple interventions provided by the manufacturer	- Machine or equipment	- Equipment operator	- Operating instructions - Consumable materials
2nd Level - Simple preventive maintenance, such as, lubricating or control functioning.	- Machine or equipment	- Technical qualification average	- Tools defined by instruction maintenance
3rd Level - Diagnosis and repair of faults by replacement of components.	- Machine or equipment; - In workshop or support	- Technical expert	- Tools and measuring equipment - Bench test - Spare parts
4th Level - All works of greater complexity in corrective and preventive maintenance	- In central workshop - specialised company	- Specialised teams	- Machines for technical support - Test bench
5th Level - Renovation, reconstruction or repair of organs performing equipment	- In specialized workshop (e.g. constructor)	- Highly specialised technical team	-Means set by the manufacturer close to the equipment used in construction

5.4.1. Organisation of preventive maintenance

The preventive maintenance plans in use in the Water Company were developed through nominations and suggestions for maintenance and upkeep expressed in equipment manuals, and have been adjusted to each facility based on the existing maintenance history and experience of those in charge of

maintenance, responsible operation, maintenance technicians and operators of the facilities of the company. In the information of the preventive maintenance plans the following stand out: the installation concerned, the description of maintenance actions, the frequency of execution, the materials used and the responsibility for implementing the measures. These maintenance plans are embedded in the computer application management maintenance sector, which allows alerting time to perform the maintenance tasks under the responsibility of the maintenance sector, as well as the sector of production/operation. In Fig. 6, we present a statement of work (IT) used in the Water Company.

CENTRIFUGAL PUMPS

OBJECTIVE: Definition of the tasks associated with the maintenance routines 1. ° level for this equipment.

SCOPE: Applies to all Centrifugal Pumps Axis Horizontal or Vertical Axis, Park Equipment of Water Company

Equipment	Centrifugal Pumps

Task	**How to Proceed - Description**
	▪ Check the proper functioning of the motor and pump; ▪ Undertake the cleaning probes or float level (where applicable); ▪ Lubricate Grasser's, where applicable and in accordance with the instructions given by Maintenance; ▪ Check lubrication cord bushing (drop by drop, if applicable); ▪ Check anomalies in valves, pipes and other accessories; ▪ Check the level of sensory noise, vibration or abnormal heating; ▪ Carry out general cleaning equipment; ▪ Record the number of hours of operation (MOD 188); ▪ Check the operation of the command given by buoys and / or level probes, by cleansing the same (when applicable).

Fig.6. Associated with IT maintenance plans 1st level

5.4.2. Organisation of corrective maintenance

There has been generally among employees in the company, but particularly in the maintenance sector, concern about the negative consequences that corrective maintenance has for the sector and, consequently, for the organisation. However, as they are aware of the inevitable need to perform such maintenance, they seek to minimise this with the implementation and monitoring of preventive maintenance actions, as well as through the promotion of measures to improve the reliability of the enabling processes and efficiency of equipment, with fewer breakdowns. Fig. 7 shows the information flow matrix, which is implemented in software maintenance used in the company.

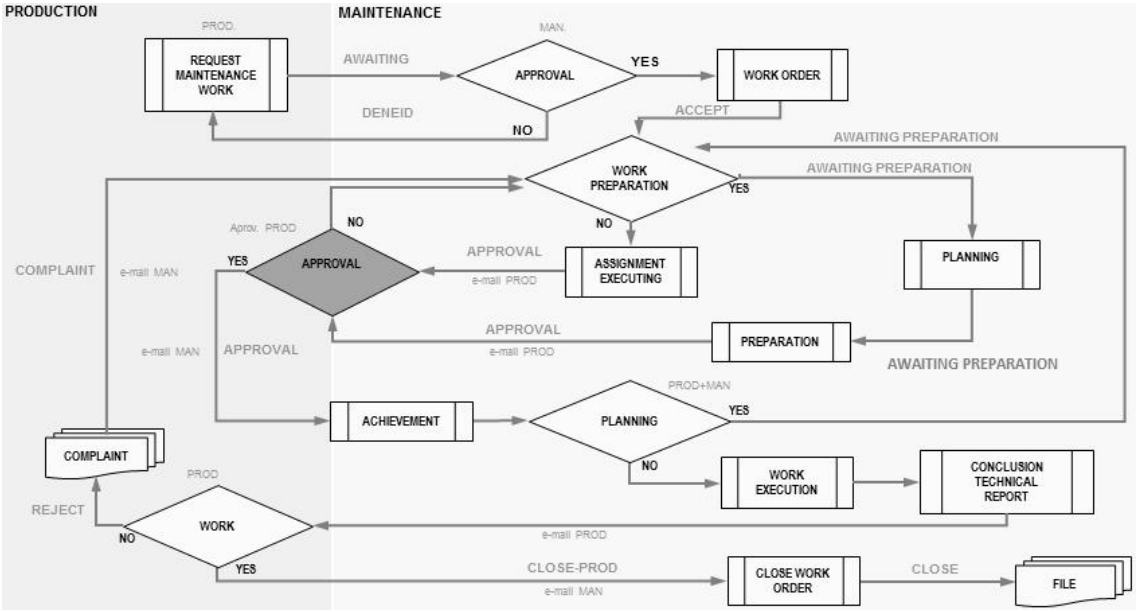

Fig.7. Functional diagram of corrective maintenance activity

5.4.3. Maintenance organisation improvement

Usually, these interventions which result from the opinions and suggestions proposed by stakeholders direct production processes, based on practical experience. With this attitude, it appears that the production operators and maintenance technicians responsible for maintenance and operation try to contribute in an active way to optimise the company's activities as a way of monetising and optimising the available resources. It is found that the functional structure for this type of maintenance action follows the steps of the functional matrix previously described for corrective maintenance work.

5.4.4. Priorities in the maintenance activity

Execution of (OT) is developed according to a priority order for its realisation, i.e., depending on the severity of the damage, or consequence to the process, facility, or the physical integrity of its employees. The company imposes five levels of intervention and priority action for the servicing sector, as shown below:

i) Priority 1 emergency – all jobs that can be performed during the next scheduled stop.
ii) Priority of urgency 2 – programme all jobs that do not affect the system of water supply, or the normal operation of the company's services.
iii) Priority urgency 3 – corresponds to faults which can affect partially the water supply system, without influencing short-term reduction in activity.
iv) Priority Emergency 4 – corresponds to malfunctions that may affect the water supply system partially with reduction of productive activity or safety equipment.
v) Emergency Priority 5 – corresponds to failures that require immediate intervention, which put at serious risk the system of water supply, human safety and/or facilities.

Associated with levels of priorities, the Water Company also stipulates a target for a period of intervention/response (OT), corresponding to each level of urgency, these being:

Priority 1 emergency – One month
Urgent priority 2 – Fifteen days

Urgent priority 3 – One week
Priority urgent procedure 4 – 48 hours
Urgent priority 5 – Immediate

With this measure, it appears that the company tries to instruct and guide their employees with rules of engagement, demarcating priority as all maintenance services that in the short term may compromise the objectives of their business.

6. Contribution of maintenance to the company under focus

Whereas public sector treatment and water supply should be understood, in terms of quantity and quality, as a duty of companies operating in this sector, and a fundamental right of citizens, we present a summary of the contributions that demonstrate the importance of the activity and the maintenance for the Water Company to achieve the objectives it sets itself and that underlie its existence:

i) The proper management and maintenance activity sector, particularly the intensification of planned maintenance actions and autonomous maintenance practices, promotes in a direct way the sustainability of the company, to the extent that this enables continuous operation and availability of operative facilities, allowing the increase of the life cycle of the equipment installed;

ii) The high technological component and strong automation of installed water treatment and supply, leading to the necessity of the sector to maintain the activity of the company. Whereas installations operate mostly in automatic mode, lacking in some cases monitoring of classroom processes and production stages, the efficiency of maintenance is a guarantee of the reliability of the operations of the company;

iii) The social responsibility on human health and environmental preservation inherent to the sector's Corporate Water Company must be understood not only as a goal, but rather as an unconditional premise of the company's activity. Given the above, it appears that the maintenance sector should be taken as one of the main agents that contribute to the quality required in the production processes. The proper performance of the maintenance sector before the equipment and production facilities, ensures that public water supply is carried out with high standards of quality and quantity, directly contributing to the maintenance of certification obtained from SGI;

iv) Given the significant economic restraint, which guides Portugal, the service sector, specifically in this business activity, it is revealed to be a key player, as it allows optimisation of production equipment, adapting them to their specific needs. To this extent, the servicing sector reduces cost overruns, particularly with investments around new equipment, as well as through the implementation of solutions to reduce costs with the use of energy resources;

v) For proper and regular maintenance, it is essential to maintain the safety and reliability of the equipment, as this allows to be detected and eliminated dangerous situations that could lead to accidents and/or health problems for the interventional agents of the company;

vi) Finally, the activity and the maintenance sector proves to be a strategic partner in meeting the targets set by the aforementioned investment programme currently underway at the Water Company. Thus, it is easily proven to influence and maintain the objectives proposed for the execution and completion of this plan through the following: increased levels of quality and service; implementation of tariffs to consumers, which are fair and consistent with its economic capacity; renovation and rehabilitation of facilities; elimination of inefficiency costs, increased

productivity and competitiveness of the sector, with solutions that enhance the efficiency of the company; ensure preservation and control of pollution from processes and production facilities.

Regarding the TPM philosophy, addressed in this work, although the company does not assume full implementation of this philosophy in its organisation, it is a positive factor and stimulates the activity of maintenance that adopts a set of practices associated with this methodology, such as:

i) Autonomous maintenance – it turns out that the organisation has agreed on a set of maintenance actions, which is part of the daily tasks of the production operators. This autonomy, participation and involvement of operators in maintenance tasks improves the efficiency of the facilities and identifies early deterioration of the installed equipment as a way of keeping the basic operating conditions of the equipment, and promoting the improvement of production activities. This practice also allows maintenance technicians to request greater complexity and technical requirement.

ii) The definition of tasks and responsibilities for action – a clear definition of maintenance tasks responsibilities of the operation and maintenance sector, resulting in the commitment and motivation of its employees through proactive participation in their daily tasks as well as through the proposed improvements to processes suggested by them;

iii) Planned maintenance – with the implementation of preventive maintenance plans, the company tends to raise the awareness of its employees to eliminate the stoppages of facilities and processes resulting from equipment malfunction, thus allowing it to minimise the flaws and defects at the lowest cost.

iv) Education and training – it seems that this practice is a constant and a priority in the organisation of the company, to the extent that frequent training has been developed with the aim of providing employees with new skills and knowledge, enabling them to act correctly and in autonomous maintenance activities.

v) Maintenance Quality – this practice is mainly carried out by production operators through their control tasks of the treatment processes, in direct collaboration with agents who analyse water quality during the stages of production. Such actions allow for the reliability of the equipment, ensuring the required quality standards at each stage of treatment, by identifying the possible causes that may induce deviations. These activities fall under the verification and analysis of the results in comparison with the standard values previously defined, in order to prevent defects, and anticipate the resolution of any problems.

vi) Control and initial improvements – given this practice, the company demonstrates its responsiveness to the opinions of its employees through the development of new ideas, thus allowing the implementation of measures to improve the adequacy of equipment and treatment processes, and to increase their productivity. With this attitude, the company tends to increase the motivation of employees, promoting a culture that values its human resources to achieve the objectives it sets itself.

vii) Health, safety and environmental monitoring – in this context, due to the requirement of the service provided by the Water Company, there is high concern by the company about the issues targeted for environmental monitoring, to the extent that this directs and controls the activities of its employees in terms of maintenance tasks, including the collection of waste oils, resulting from planned maintenance tasks, and the directives for action on the environmental impact of its activities. With regard to health and safety practices, it appears that the company often promotes awareness training for its employees to use personal security equipment, in order to avoid accidents or diseases that compromise their employment. Symptomatic of this concern is the importance the Water Company gives to these practices, and which is revealed in their certification in Quality, Environment and Occupational, health and Safety.

Given that currently the maintenance sector of the company is largely driven by the practices that fall under the TPM philosophy, it is thought that the full implementation of this philosophy in the structure of the company may be important to the performance of sector maintenance and consequently for the organisation. Thus, considering that the company is already on this path, providing material resources, management tools and instilling this culture in its employees, who are directed towards such practices, with the major barriers that lead to the failure of this philosophy, the consolidation of current practices and adoption of other measures around this methodology could be implemented without major difficulties, and reduced financial outlay. The successful implementation of TPM philosophy starts with a commitment and recognition from the top management of the benefits of implementing their practices in the organisation (Ahuja and Khamba, 2008). Given the above, if the Water Company implements this philosophy in the organisation, it is suggested that the course charted for the final goal has as its starting point this idea.

7. Conclusion

Breakdowns and equipment failures generate losses, risk accidents and damage the environment, in addition to influencing negatively the costs and, therefore, the competitive position of any company. This article demonstrates the importance of the business sector in promoting the maintenance of reliable, efficient and available equipment and processes, in order to ensure the sustainability and growth of the company under focus, without which it is not possible to achieve the objectives proposed in the competitive context of fiscal restraint imposed by the Portuguese State. Thus, is the responsibility of everyone to contribute in an active and practical way to stimulating the activity of maintenance within this business sector, as well as enhancing awareness of all interventional agents for maintenance,. Therefore, everyone will have to face a strategic partner in the short, medium and long term, without which viability and sustainability will certainly be compromised.

Theoretically this paper contributes to systematize the evolution of the concept of maintenance giving also an insight on the new denominations that have been suggested for this critical activity. Moreover, the main contributions of the TPM for improving the performance of the production function are identified.

This research gives managers an insight on the main critical maintenance activities for improving the performance of companies and the barriers that should be overcame to a successful implementation of the TPM, such as: cultural resistance to change, partial implementation of the TPM, overoptimistic expectations, lack of well-defined routines to achieve the objectives of this methodology, lack of training and education, frequent changes in the schedule of availability of machines for interventions lack of organisational communication and a wrong way of implementing TPM. The autonomous maintenance (AM) should be implemented in the companies to guarantee the success of TPM. Using the approach suggested in this paper it will be interested to develop the same research but with a survey with a large sample of companies from different sectors to perform a benchmarking analysis of the TPM implementation and the main benefits reached with it**.**

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