ISCTE Business School
Instituto Universitário de Lisboa

BENEFITS OF MAINTENANCE MANAGEMENT SOFTWARE

A study on Portuguese market

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- Spine -

Resumo

Num mundo em que a manutenção tem evoluído ao longo dos anos, é esperado que o investimento tecnológico continue a crescer e se torne ainda mais importante no desenvolvimento da manutenção, contribuindo para a rentabilidade das organizações.

Esta dissertação procura identificar os benefícios obtidos pelas empresas após a implementação de software de gestão de manutenção. A partir de uma extensa revisão de literatura e contatos realizados com a indústria, identificaram-se um conjunto de benefícios que foram incluídos num questionário realizado a empresas Portuguesas de diferentes setores, com o intuito de verificar o nível de medição de cada benefício e avaliar a aceitação do projeto de software de gestão de manutenção nas organizações.

Os resultados demonstram que muitas empresas confirmam a obtenção dos benefícios sugeridos no questionário. No entanto, esta investigação revela também que poucas organizações avaliam os benefícios de tal forma que consigam traduzi-los em valor financeiro.

O estudo contribui com conclusões que se baseiam em pesquisa empírica, disponibilizando dados de mercado que são úteis tanto para fornecedores de software de gestão de manutenção como para empresas que utilizam ou pretendem vir a utilizar este tipo de sistema.

Keywords: maintenance, maintenance management software, CMMS, benefits management

JEL Classification: M15, M31

Abstract

In a world where maintenance has evolved over the years, it is expected that technological investment will continue to grow and become even more important for the development of maintenance, contributing to the profitability of organisations.

This dissertation seeks to identify the benefits obtained by organisations after the implementation of maintenance management software. From an extensive literature review and contacts made with the industry, a set of benefits were included in a questionnaire to Portuguese companies belonging to different sectors, with the purpose of assessing the level of measurement of each benefit and evaluating the acceptance of the project of maintenance management software in organisations.

Results demonstrate that many companies confirm the achievement of the benefits suggested in the questionnaire. However, this research has also shown that few organisations evaluate the benefits in such a way that translate the benefits into financial value.

The study contributes with findings that are based on empirical research, providing market data that are useful for both vendors of maintenance management software and companies that use or intend to use this type of system.

Acknowledgements

After conducting a study such as this, it is indispensable to recognise the contribution of all those who, directly or indirectly, have made this work possible.

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Finally, I dedicate this work to my parents for their love and support throughout my life.

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List of Abbreviations

APMI – Portuguese Maintenance Society

BRC – British Retail Consortium

CEN – European Committee for Standardization

CMMS – Computerized Maintenance Management System

CRM – Customer Relationship Management

EAM – Enterprise Asset Management

E-Maintenance – Electronic Maintenance

EN – European Norm

ERP – Enterprise Resource Planning

FDA – Food and Drug Administration

FMEA – Failure Mode and Effect Analysis

IFS – International Featured Standards

IOT – Internet of Things

ISO – International Organisation for Standardization

IT – Information Technology

KPI – Key Performance Indicator

LCC – Life Cycle Costing

MRP – Material Requirement Planning

MTBF – Mean Time Between Failures

MTTR – Mean Time To Repair

MWT – Mean Waiting Time

OEE – Overall Equipment Effectiveness

OHSAS – Occupational Health and Safety Assessment Series

RCM – Reliability Centred Maintenance

TPM – Total Productive Maintenance

TQM – Total Quality Management

WO – Work Order

1. Introduction

In a world of constant technological evolution, maintenance plays an important role in guaranteeing the proper functioning of assets, ensuring that they are intervened in the opportunities and with the right range to prevent failures or loss of performance and, in case this happens, restoring them in good operating conditions at the earliest, all at optimised overall cost (Cabral, 2006).

We see different cases where problems related to lack of information and communication in maintenance are identified, and if we remember serious disasters in the past such as the Bhopal chemical leak (1984) or Deepwater Horizon oil spill (2010), we realise that maintenance simply cannot fail. In addition to safety, environment or quality care, that must be essential, there are many other reasons why companies should be committed to good maintenance management. In fact, maintenance can represent a competitive advantage for organisations, either by increasing production capacity, reducing costs or, for example, increasing quality.

Maintenance has evolved over time and it is expected that the contribution of technology development, combined with a good maintenance management, continue to allow long-term profitability for organisations. This study addresses the purpose of CMMS (Computerised Maintenance Management System) and why it is considered today an indispensable tool in organisations that want to have a well-structured and organised maintenance. According to Wireman (2005), the maintenance management process should be composed of different levels, and the process should be based on preventive maintenance, followed by the definition of important aspects such as stores and procurement, CMMS, interpersonal training and work flow system. Only after these concepts are in place will it make sense for the maintenance area to focus on optimisation, putting into practice concepts such as predictive maintenance or the use of methodologies such as TPM (Total Productive Maintenance) or RCM (Reliability Centred Maintenance).

Several authors have studied the advantages of information systems for maintenance (e.g. Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001; Wireman, 2005) and in fact, it is possible to identify many problems in different areas of maintenance that can be solved

with the support of a CMMS. Despite the evident importance of CMMS use nowadays, much of the available literature holds the view that sometimes CMMS are not fully exploited by companies or deployment is not successful due to the lack of fulfilment of promised benefits (e.g. Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001; Wireman, 2005). It is also important to remember the existing discussion around the concept of productivity paradox since the famous words of the Nobel Prize for economics Robert Solow (1987) who stated, "You can see the computer age everywhere but in the productivity statistics". This controversy reinforces the importance of studying this topic and presenting current perspectives that contribute to better decisions in the maintenance area, both from the perspective of CMMS vendors as well as from a perspective of companies that use or intend to use a CMMS to support maintenance management.

This dissertation examines the advantages of maintenance management software and identifies the benefits resulting from the implementation of these systems by Portuguese organisations. Although there is already considerable literature about maintenance software, it is more common to find studies related to benchmarking of the use of software and respective maintenance practices or about the procurement process (e.g. Kans, 2012; Lemma, Y. et al., 2012) rather than studies that address the benefits of using software. It should also be noted that much of the existing research on benefits of the use of maintenance software is applied to specific industries or business case studies (e.g. Mjeman and Mewta, 2003; O'Donoghue and Prendergast, 2004), which also served as a motivation for this study to be developed with a broader sample that allows conclusions to be drawn about the market.

While some research has been carried out about the reality of maintenance in Portugal (e.g. PSE, 2017), no studies have been found which analyse the level of benefits obtained through the use of maintenance management software by Portuguese organisations. This reality was also confirmed through a contact established with APMI (Portuguese Maintenance Society), who recognised the importance of carrying out a national study on the subject. In accordance with Fraser et al. (2015) and Simões et al. (2011) who identify the need to provide more empirical examples in the maintenance area, this study contributes with findings that are based on market data and allow an understanding of the practical context of the use of maintenance management software.

1.1. Goal and Objectives

In this context, this dissertation aims to answer the following question: "*What are the benefits of maintenance management software use in Portuguese organisations?"*. Thus, it is presented an analysis on the topics of maintenance, maintenance management software and benefits management, which are the basis of a questionnaire for a group of Portuguese companies that use maintenance management software. This research seeks to achieve the following objectives:

a) Understand to what extent organisations can measure the most common benefits and assess the level of improvement resulting from the use of maintenance management software;
b) Identify the real benefits of using maintenance management software;
c) Assess whether organisations that have implemented this type of software consider the project as successful.

There are several benefits associated with maintenance software, having been selected for this study a set of benefits considered most relevant. As the questionnaire is directed to companies that own maintenance management software, it is expected that benefits obtained from the use of this type of software by Portuguese companies will be assessed, thus contributing with data that help organisations to understand the impact of maintenance management software and to identify possible improvements for these systems.

1.2. Motivation

The emergence of the topic of this dissertation was based on the professional experience of the author in the area of maintenance management software. In addition to responding to the problem statement which was already been mentioned, one of the motivations to address this subject is the possibility of analysing from a marketing perspective the perception of the users of maintenance management software and to better understand the Portuguese reality in this area, more specifically with the identification of some patterns related to:

a) Critical factors to assure the success of maintenance management software;
b) Features of maintenance management software that are most commonly used;

c) Important factors for the purchase decision.

It is expected that this study reveals opportunities in the market of maintenance management software and that it proves to be a contribution to the literature, stimulating further research on these systems for the future.

1.3. Dissertation Structure

This dissertation is structured in five sections. Considering the objectives mentioned above, in Section 2, a literature review is presented focusing on three key topics: maintenance, information systems for maintenance management and benefits management.

The methodology of this study is described and explained in Section 3 and the results and discussion of the research are presented in Section 4.

Finally, in Section 5, the conclusions of this study are presented, together with research limitations and some recommendations for future research.

2. Literature Review

2.1. Maintenance

According to the European standard on maintenance terminology (CEN, 2007a), maintenance can be defined as the "combination of all technical, administrative and managerial actions during the life cycle of an item to retain it in, or restore it, to a state in which it can perform the required function".

Cabral (2013) mentioned that beyond the strictly technical scope of maintenance, there are a wide range of activities belonging to maintenance function, such as to comply with legal requirements, certification, safety and social sustainability, the latter described as the responsibility of the organisation to be able to demonstrate at any time that is conducting its activities using practices that are safe, environmentally friendly and socially accepted. In fact, maintenance has evolved along the years as described in Section 2.1.1, being recognised nowadays as an area with great responsibility within organisations.

2.1.1. Evolution of Maintenance

Despite maintenance function tended to be perceived as a cost centre in the past, the paradigm shifted when organisations started to realise that maintenance, if well managed, can reduce costs and increase productivity (Cato and Mobley, 2001).

Moubray (1997) explored how expectations of maintenance changed over the time and determined the existence of three generations as presented in Figure 1. The first generation represents the period before the Second World War during which industry was not highly mechanised and equipment was simple, reliable and easy to restore. Avoiding failures and downtime were not among management concerns and interventions were typically corrective, apart from simple actions such as cleaning, servicing and lubrication.

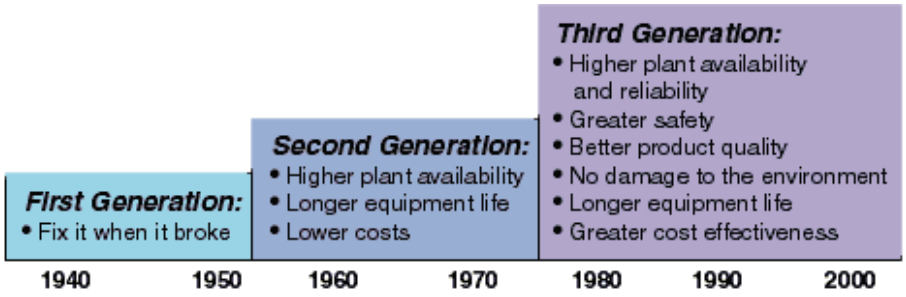


Figure 1 Growing expectations of maintenance (Moubray, 1997)

The second generation was driven by the industrial changes caused by pressures of the Second World War. The increase in demand for goods and the shortage of industrial labour switched the focus to mechanisation. Industry became more dependent on machines and managers began to pay more attention to downtime, which in turn led to the appearance of preventive maintenance concept. Maintenance planning and control systems have also emerged due to the need of controlling maintenance costs which were growing rapidly. Maintenance became an important support function for production and manufacturing (Parida and Kumar, 2006).

The third generation began on 1970's and is characterised by the recognition of reliability and availability as being important issues for organisations. New maintenance techniques were introduced, greater automation and mechanisation, and it is clear that failures have impact on quality standards. The integrity of assets started to be addressed not only from a cost perspective but also as a matter of acting according society's safety and environmental expectations, since neglecting compliance with standards in these areas may mean the end for an organisation. The growing dependence on physical assets made operating costs and owning costs to increase, which led in turn led to the need of keeping assets working efficiently for a long time. These facts contributed to the increase of maintenance costs in absolute terms and as a percentage of total expenditure.

2.1.2. Maintenance Types

While a variety of nomenclatures is used in literature to classify maintenance types, in this dissertation a definition proposed by EN 13306:2007 standard (CEN, 2017a) will be presented, as shown in Figure 2. In general, maintenance interventions could be divided into two main categories, specifically Preventive Maintenance and Corrective Maintenance.

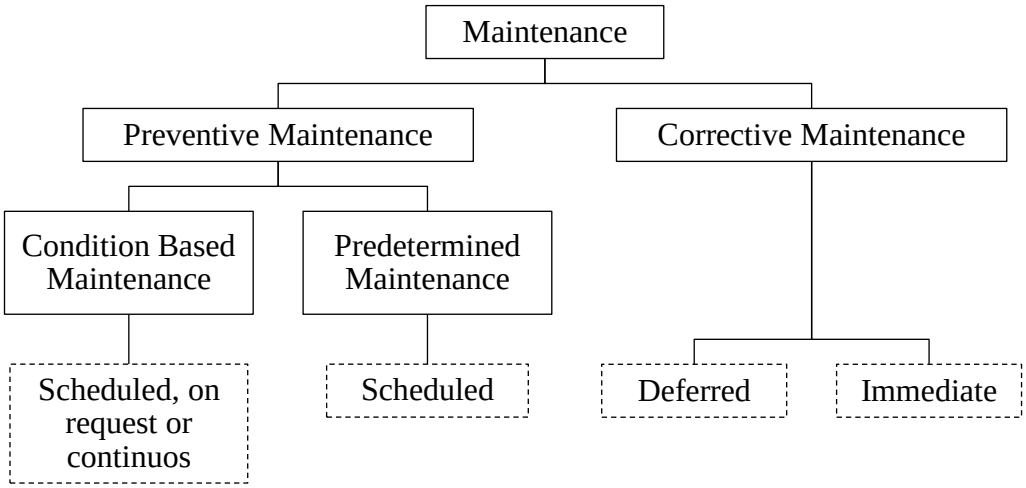


Figure 2 Maintenance types according to EN 13306:2010 (CEN, 2007a)

1.1.2.1. Corrective Maintenance

Corrective maintenance is performed after a failure is detected and consists of the activity of placing the asset in a state that allows it to perform its required function. The EN 13306:2007 standard (CEN, 2007a) identifies the existence of two types of corrective maintenance, which can be deferred and immediate:

- Deferred corrective maintenance: This type of maintenance consists in not acting immediately after detecting a fault, but delaying the intervention according to certain rules;
- Immediate corrective maintenance: This type of maintenance is executed after detecting a fault to avoid more problematic consequences.

Since the repair is performed after the loss of function of the asset, higher costs are expected with this type of maintenance, especially if the intervention must be done immediately and no planning has been done.

1.1.2.2. Preventive Maintenance

Preventive maintenance is carried out to reduce the probability of equipment failure and can be divided into predetermined maintenance and condition-based maintenance, which means that it may be based on time or on condition.

Predetermined maintenance can be defined as the preventive interventions (e.g. lubrications, inspections or routines) that are based on calendar or on running records

(e.g. operating hours, km, etc.). Condition based maintenance is carried out based on the operating condition of the equipment, when symptoms are detected prior to the loss or significant reduction of function.

Ben-Daya et al. (2016) points out that carrying out maintenance activities involves costs for organisations and refers to the existence of an optimal level of preventive maintenance effort. In other words, there is a reduction in corrective maintenance costs when there is a preventive maintenance effort, but this effort should be measured because it also involves costs. Wireman (2005) notes that due to inefficiencies, the cost of corrective maintenance is 2 to 4 times higher than preventive maintenance and suggests that organisations should have a ratio of 80% of preventive maintenance to 20% or less of corrective maintenance.

2.1.3. Maintenance Management

Maintenance management encompasses all the activities that establish the objectives, strategies and responsibilities relating to maintenance and its implementation, through methods such as planning, control and improvement of maintenance (CEN, 2007a). Maintenance management must be aligned with organisation's goals and, as Pintelon and Parodi-Herz (2008) refer, it is a complex process that involves different aspects related to technology, operations and logistics. In fact, the maintenance manager is responsible for planning and implementing different actions, ideally with the data support, and decision making is required in strategic, tactical and operational levels (Ben-Daya et al., 2016; Van Horenbeek and Pintelon, 2014).

Wireman (2005) argues that maintenance strategy contributes to the goal of increasing profits by decreasing expenses and maximizing capacity, and lists some of the typical maintenance management objectives as follows: maximise production at the lowest cost; high quality, and within optimum safety standards; identify and implement cost reductions; provide accurate equipment maintenance records; collect necessary maintenance cost information; optimise maintenance resources; optimise capital equipment life; and minimise energy usage and minimise inventory on hand.

Maintenance exists in organisations from different sectors and may represent a substantial part of the total operating costs. The study conducted by PSE (2017) in the Portuguese market, has shown that for 51% of organisations, maintenance costs represent more than

10% of their overall costs. It should be noted that these values vary from sector to sector, and in Portugal the industries of Transport and Logistics, Energy, Oil and Fuel are those where maintenance assumes a greater weight in the overall cost structure of companies. This information is in line with the emphasis given by Parida and Kumar (2006) to heavy and capital-intensive industries, where maintenance plays a critical role by ensuring that equipment operates in full safety conditions.

Although maintenance may involve high costs, the cost of not taking maintenance seriously is a cost that organisations should not be able to sustain in the medium to long term (Fraser et al, 2015). It is reasonable to say that maintenance contributes to long-term profitability of organisations, and therefore it should assume a strategic function (Al-Sultan and Duffuaa, 1995; Velmurugan and Dhingra, 2015). So that the maintenance area is properly recognised as a value for organisations and not as a mere cost centre, it is crucial that stakeholders realise that there is a clear distinction between what are the direct costs and indirect costs on maintenance. Direct costs are the visible and quantifiable costs of the total maintenance costs, such as labour, materials, contracts or overheads. The real costs of maintenance, which actually express its performance, are the direct costs plus those that consider the consequences of maintenance (Cabral, 2006; Wienker et al., 2016). The latter, referred to as indirect costs, are more difficult to identify but nevertheless there should be an effort to quantify them, since they account for about four times the direct costs (Cabral, 2006). Wienker et al. (2016) identify some examples of indirect costs such as costs with higher energy consumption, lower quality, reduced asset life, environmental issues, safety risks or lost production. In fact, it does not make sense to measure maintenance performance based only on the financial impact of improving the internal processes of the maintenance area, but rather to assess the impact that maintenance strategies have on other areas such as production, logistics, customers and even employees (Kumar et al., 2013).

Many topics regarding maintenance management could be explored in this section, however this dissertation focuses on the contribution of CMMS to maintenance, which is the basis of good maintenance management and which is recommended in several management methodologies that can be implemented in the maintenance area.

2.1.5. Measurement of Maintenance Performance

A system to measure maintenance performance is essential for organisations that want to manage and must be in place to allow the monitoring of quantitative and qualitative data related to maintenance goals that can highlight opportunities for improvement and support sound decisions (Simões et al., 2011; Tsang et al., 1999; Wireman, 2005). Parida and Kumar (2006) provide a list of reasons to explain why maintenance performance metrics are demanded:

- to measure value created by the maintenance to organisation;
- to justify investments made in maintenance;
- to revise resource allocations;
- to understand the impact of maintenance on health, safety and environmental issues;
- to focus on knowledge management;
- to adapt to new trends in operation and maintenance strategy;
- to adopt organisational structural changes.

Previous studies have emphasized the importance of having the maintenance management indicators aligned with the goals, business strategies and specific objectives of the organisation (Cabral, 2013; Simões et al., 2011; Tsang et al., 1999; Wireman, 2005). Simões et al. (2016) reveal that even though most Portuguese organisations implement and use metrics with consistency, they can still improve the use of strategic indicators, incorporating metrics that allow the maintenance strategy to align with the overall strategy of the organisation.

According to Cabral (2006), management indicators are useful to support decisions, compare activities between different years and with competitors, evaluate benefits of maintenance policy, prepare a budget and help to identify problems. The benchmarking practice should also be highlighted, since it allows the comparison of indicators within and outside the same industry and might represent a source of improvement for organisations.

The EN 15341 standard published by the CEN (2007) classified the maintenance key performance indicators into three groups: economical, technical and organisational indicators. Cabral (2013) notes that the elected set of indicators for maintenance

management should constitute a Balanced Scorecard and recommends that the right indicators be chosen and used for a sufficiently long period so that conclusions can be drawn. It should also be said that when defining the maintenance indicators to be used, it should be considered not only their predicted value, but also the ease of obtaining data to calculate them. As mentioned by Cabral (2013), in order to take advantage of indicators, it is necessary to have the parameters from which the indicators are formulated, namely time related factors, human effort related factors, number of events, cost related factors and value related factors. Obtaining these parameters requires the existence of an organised data collection and processing system, and in this sense, an appropriate software maintenance is an indispensable tool for the expeditious way in which indicators are obtained (Cabral, 2013; Wireman, 2005).

Several maintenance management indicators have been proposed in literature, and therefore, it must be noted that a good selection of indicators to be used by the organisation should imply that not too many indicators are selected (Cabral, 2017). There is not really a single standard list of indicators that should be used, but it is important to highlight some of the most common indicators:

- Cost of corrective maintenance vs total cost of maintenance (CEN, 2007b; Simões et al., 2011; Wireman, 2005)
- Cost of preventive maintenance vs total cost of maintenance (CEN, 2007b; Simões et al., 2011)
- Cost of maintenance vs company revenue (Kumar et al, 2013)
- Cost of maintenance vs Unit produced (Wireman, 2005)
- Availability / Unavailability (Cabral, 2013; Kumar et al, 2013; Simões et al., 2011; Wireman, 2005)
- LCC (Life Cycle Costing) (Lemma, Y. et al., 2012; Pintelon et al., 1999)
- MTBF (Mean Time Between Failures) (Cabral, 2013; CEN, 2007b; Kumar et al, 2013; Simões et al., 2011)
- MTTR (Mean Time To Repair) (Cabral, 2013; CEN, 2007b; Kumar et al, 2013; Simões et al., 2011)

- MWT (Mean Waiting Time) (Cabral, 2013)
- OEE (Overall Equipment Effectiveness) (Simões et al., 2011)
- Failure rate (Cabral, 2013), (Simões et al., 2011)
- Rate of completed work orders (CEN, 2007b; Wireman, 2005)

2.2. Maintenance Management Software

Technology has always been evolving and during the last decades, many developments occurred in IT (Information Technology), making computers nowadays present in almost every activity in the world, including maintenance. The existence of information systems in organisations is increasingly common, and is no longer limited to medium or large companies, they are also a reality for micro and small enterprises (Crespo et al., 2015).

Several authors (Dedrick et al., 2003; Oliveira et al., 2011) argue that investment in IT has a significant and positive impact on the productivity and competitiveness of organisations and therefore IT must have considerable importance. For this to happen, it is essential to ensure that IT is aligned with business objectives and corporate strategy (Holland et al., 1999; Segarra, 1999).

Regarding maintenance, the use of computer and the development of applications for maintenance management started in the 1970s. The maintenance management systems used in the early days by organisations evolved from relatively simple applications to became today multi-user systems that are more complete and capable of support a wider range of maintenance needs (Pintelon et al., 1999). Kans (2009) described the evolution of IT systems for maintenance management throughout history and established a comparison with other organisational IT systems, concluding that in general IT systems for maintenance were built on the same structures as other IT systems.

However, as mentioned by Wilson (1984), while IT applications for finance were common in the 1970s and 1980s, IT systems for maintenance function were not so prevailing. Even during late 1990s and early 2000s, different modules such as finance and accounting, CRM (Customer Relationship Management) or MRP (Material Requirement Planning) were being introduced in ERP (Enterprise Resource Planning) systems but at that time most of them did not include a maintenance module (Nikolopulos et. al, 2003). In fact, there is still a difference between the acceptance of IT use in the finance department and maintenance department, being possible to find some small and medium-sized companies with room for improvement regarding the IT support for the maintenance area. The recent study carried out by PSE (2017) on the practices of data analysis in maintenance presented some interesting data regarding Portuguese organisations. The industry has been grouped into different stages of maturity, and the study revealed that

for 40% of the organisations, designated as Leaders, IT is aligned with the analytical needs of maintenance function, although there are difficulties accessing data and information. For 60% of companies, designated as Underperformers, the need to align IT with their analytical needs is an evidence.

Maintenance management software, also known as CMMS or EAM (Enterprise Asset Management), has been spreading more and more in organisations and nowadays is considered as a very important tool to support maintenance area. A CMMS is designed to assist in the planning, scheduling, monitoring, controlling, reporting, and other related administrative functions, for effective and efficient management of maintenance (Ben-Daya, 2016). The terms CMMS and EAM are often used interchangeably since there are no major differences in the way these types of programs function, although EAM typically extends its scope to the life cycle of assets (Gulati, 2013). It should also be noted that some of the typical features of a maintenance software may also be found in ERP software, in modules designed for the maintenance area.

The use of CMMS may have various purposes and is not necessarily specific to a certain industry. In fact, any organisation managing assets is a potential user of a CMMS. Plant Services (2005) has shown the widespread application of CMMS, identifying seven types of maintenance areas that could be covered by existing CMMS:

- Plant maintenance
- Fleet or mobile equipment
- Facilities
- Infrastructure
- IT asset management
- Service management
- Capital management

In the past, it was common to find systems that were limited to only one or two of these areas, but maintenance has been gaining importance over time and the need to satisfy customers have led companies who develop CMMS to extend the functionality and breadth of their software. Nowadays organisations such as industrial plants, airports or oil companies often use the same software to manage all the functional areas mentioned above.

Indeed, a CMMS is a tool that allows management to identify areas with good performance and points that can be improved in maintenance, emphasizing the realisation that a CMMS is a pre-requisite for a world class maintenance given its importance in decision-making (Labib, 2004; O'Donoghue et al., 2004). Moreover, there are many benefits associated to the use of CMMS, as described in Section 2.2.3, and as noted by Wireman (2005), the use of maintenance management software is part of a basic principle that only after being in practice will enable the organisation to implement methodologies such as TPM or RCM. Nevertheless, it is important to highlight that a CMMS should be looked as a tool to support continuous improvement, and not as an aim by itself (Wireman, 2005).

2.2.1. Capabilities

A maintenance management software must have a set of resources related to equipment/asset, material, work management, analysis, and as noted by Cabral (2013), it should have a user-friendly interface, that appeal to simple and direct operations to allow the maintenance professional to be focused on its core activities and not waste time with unnecessary bureaucracy.

A description of some of the main capabilities existent in a maintenance management software are listed below (Bagadia, 2006; Cabral, 2013):

Equipment/Asset

- Equipment/asset inventory with data such as location, technical specifications, photo and documents;
- Running records in accordance with operating history of equipment (hours, km, etc.) and fuel supply records;
- Management of maintenance plans associated to each equipment with information about safety procedures, tasks to be performed, as well as planned man hours, materials and third-party services;
- Recording of parameters;
- Material listing by equipment;

- Management of rotating assets.

Material

- Article master file for single encoding materials with information about location, unit, unit cost and minimum and maximum stock levels:
- Stock management of warehouse materials;
- Material inventory;
- Minimum stock alerts and replacement suggestion;
- Store entries of material;
- Store outputs of material;
- Transfer and return of materials.

Work Management

- Scheduling of preventive maintenance based on calendar or running records, or both, whichever occurs earlier.
- Planning and record of man hours, materials and third-party services for maintenance works, with possibility of comparing in real time the planned costs versus real costs;
- Planning and management of WO (Work Orders) of any type, planned or not;
- Performing maintenance requests;
- In case of failures, possibility of reporting causes, symptoms and components;
- Possibility of obtaining times (maintenance time, repair time, downtime related to maintenance and failures);
- Accumulation of a traceable history.

Purchasing

- Preparation of purchase orders for material;

- Elaboration of purchase orders for third-party services;
- Requests for quotation;
- Receiving orders.

Analysis

- Equipment failure history;
- ABC analysis;
- FMEA (Failure Mode and Effect Analysis);
- Predictive maintenance analysis;
- Providing different maintenance KPI (Key Performance Indicators) such as availability, cost of preventive maintenance vs total cost of maintenance, failure rate, MTBF, MTTR, MWT, etc.

Budgeting

- Planning and control of maintenance budget.

2.2.2. Critical Factors for the Success of Maintenance Management Software Projects

It is known that some implementation projects of maintenance management software end up failing (e.g. Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001; Wireman, 2005). Cabral (2013) even states that exploiting only 50% of the resources of a maintenance management software application is a common practice in many companies that use this tool. Nevertheless, the positive impact of this type of software is evident today, and it is important to reflect on the factors that contribute to the success of these projects in organisations. Prior to the acquisition of a maintenance management software, it is important that the organisation is aware that the implementation of such systems is only one step along the way. Cabral (2013), for instance, argues that moving from an organisation of traditional reactive style to an organisation of the best level can take three to five years.

Some of the most important factors for the success of the project of maintenance management software are presented in this Section, having been included in five distinct areas: Implementation support services, Change management and Buy-in from top management, Maintenance procedures, Project and Software attributes.

Implementation support services

The experience of a company that implements maintenance management software and its technical support can be fundamental in making decisions that add value to the project and to avoid common mistakes in the implementation of this type of software (Bagadia, 2006; Plant Maintenance, 2004).

Change management and buy-in from top management

One of the most mentioned aspects in literature (Bagadia, 2006; Plant Maintenance, 2004; Wienker et al., 2016) is the buy-in from top management. In fact, upper-management must be fully committed to the maintenance management software project, providing the resources needed for the project and realising the return that the system will bring to the organisation. Another important aspect in the system implementation is the change management (Bagadia, 2006; Plant Maintenance, 2004; Wienker et al., 2016). It is essential that people who use the software realise the purpose of IT and the benefits they will deliver to the organisation through the changes that are being made, and that simultaneously they feel part of that change (Kans, 2008). Bagadia (2006) points out that changes in maintenance processes will be successful if certain people from the maintenance area are involved in the development of new procedures.

Maintenance procedures

The existence of a procedures manual with well-defined tasks and responsibilities is central to the long-term success of the project. According to Bagadia (2006), the project of maintenance management software involves some sophistication and in order to guarantee continuity, everything must be properly documented. As Cato and Mobley (2001) point out, a well-implemented project of maintenance management software should include standard maintenance procedures that ensure effective organisation.

Project

Within the project itself, many important factors could be addressed. In the context of IT projects, and more specifically in the approach of benefits management, which is described in Section 2.3, it is common to give focus to project benefits. This factor is fundamental, it is clear that if the proposed benefits are not achieved, the project ceases to make sense and there is no return on investment. Another important factor to note in the context of the project is an adequate user training (Amadi-Echendu and de Wit, 2015; Plant Maintenance, 2004). Amadi-Echendu and de Wit (2015) carried out a study on perceptions and acceptance of CMMS and concluded that user acceptance of technology is strongly influenced by the level of user training.

Software attributes

Factors related to the software itself, such as being user-friendly (Bagadia, 2006; Carvalho, 2014 or being appropriate for a certain company (Plant Maintenance, 2004) are also key when reflecting about the success of the project.

2.2.3. Benefits of Maintenance Management Software

Many benefits can be associated with the use of maintenance management software. As can be observed in the Benefits Dependency Network, described later in Section 2.3.1.1, the benefits are the result of changes in business, supported by enabling changes and by the technology itself. In the context of maintenance, we can say that the features of maintenance management software related to inventory centralization, work order management, spare parts management or management indicators allow the maintenance area to define procedures that lead to changes in practices, which in turn solve problems and create value not only for the maintenance area, but also for different stakeholders. Bagadia (2006) refers to excessive downtime and lack of inventory control as very common problems in maintenance and lists a variety of problems that could be solved with the support of a maintenance management software, within areas such as labour productivity, equipment availability, inventory control, quality of product or service, support of management, environment controls or maintenance controls.

Increased equipment availability

One of the benefits most associated with the use of maintenance management software is the increased equipment availability (e.g. Bagadia, 2006; Braglia et al., 2006; Mjema & Mweta, 2003; O'Donoghue and Prendergast, 2004; Plant Services, 2010). The first advantage of using a maintenance management software with regard to equipment availability is that with the introduction of a system, should be imposed the procedure to record the downtime of machines or systems. Recording downtime can be done manually but is incomparably less efficient than recording on a digital system, designed to automatically schedule preventive maintenance, avoiding neglect, and which allows to easily extract and control a set of indicators such as availability/downtime.

As Bagadia (2006) refers, with the change from a reactive maintenance to preventive maintenance, organisations should increase the ratio of planned work to unplanned work, resulting in a decrease in downtime. The maintenance management software should be a support to ensure this change of approach in the maintenance area, an adequate preventive maintenance plan should ensure that equipment work in good conditions, reducing the number of corrective maintenance work. It is also important to mention the role of predictive maintenance in improving the availability of equipment, being that monitoring equipment condition with sensors should allow the detection of potential problems, and in such cases, the system should generate a notification for the maintenance area. The maintenance management software also allows to quickly identify common failures and repairs, which results in a reduction of breakdowns and an increase of the equipment availability. Another contribution of the use of CMMS to increase the availability of equipment has to do with spare parts, meaning, if there is greater control with warehouse management, the likelihood of out-of-stock in spare parts that are necessary for maintenance work is reduced.

Cato and Mobley (2001) also make a distinction between availability and reliability, considering that the latter encompasses not only availability but also product quality, throughput capacity, and total operating costs, and point out that the use of a maintenance management software is fundamental to an optimum equipment reliability, reinforcing that before reliability can be improved, organisations must first be able to measure and track the reliability. The authors also noted improvements in equipment reliability that range between 30% to 50% after the first year of implementing condition monitoring and

a maintenance management software. In a study applied to a cement company, Mjema & Mweta (2003) have also found that the introduction of a maintenance management system led to an increase of 15% in equipment availability. A worldwide survey conducted by Plant Maintenance (2004) has shown that 46,6% of the companies reported significant or some improvements in equipment availability.

Increased labour productivity

Increasing productivity is a benefit that is often associated with IT implementation and is also applicable to maintenance management software. Several authors (Bagadia (2006); Cato and Mobley, 2001; Mjema & Mweta, 2003; O'Donoghue and Prendergast, 2004; Wienker et al., 2016; Wireman, 2005) mention this benefit because of the importance of employees spending less time on tasks that can be streamlined while also gaining time to do other things that are important in maintenance and provide better service.

With the acquisition of a maintenance management software, organisations can no longer be dependent on paper or dispersed digital files, and now have a centralised system where employees have access to accurate information that is readily available such as maintenance history, planned works, work instructions and technical documentation, necessary spare parts and tools. There are several impacts on the productivity of labour, for example, the fact that employees have no interruptions or delays in the search for information, so that they can take decisions faster. This can lead to avoidance of emergency repairs, less need to reschedule jobs, make equipment available when jobs are scheduled, and even reduce the supervisor's time to intervene in follow-up tasks. More difficult to measure, but also important to mention, is the gain of employee morale derived from the use of this type of systems.

The use of maintenance management software also allows the organisation to have access to reports and performance indicators to measure and monitor employee performance. With this, it will be able to better evaluate employees, improve the learning process and at the same time, it is a way to ensure that the maintenance area has sufficient manpower to carry out maintenance tasks.

Another aspect that must be addressed is the tracking of spare parts with the use of the software for warehouse management. Two major impacts can be observed at this level, employees will know where the parts are located and can also prevent out-of-stock.

Lengthened equipment lifetime

Two common problems in the maintenance area have to do with the cost of replacing equipment and with the justification of either upgrading existing equipment or keeping current equipment. Bagadia (2006) reveals the importance of making an equipment replacement analysis for decision making and recalls that equipment life can be increased if a preventive maintenance program is in place.

In fact, by having a maintenance management software with equipment inventory and maintenance data (man-hours, spare parts used, costs, etc.), together with an adequate preventive maintenance schedule with alerts for all interventions, companies are closer to obtain a maximum life cycle (Braglia et al., 2006; Plant Services, 2010; Wireman, 2005). This approach can keep the equipment effective, valuable and reliable for longer, avoiding replacement costs.

Ensured compliance with the legislation in force

Maintenance management software is commonly associated with laws that must be followed, and in fact, it is natural that companies that care about the quality and comply with certifications that cover the maintenance area, have a maintenance management software. Sometimes the legal requirement or certification requirement is even the main reason for acquiring such systems.

Different data recorded in the maintenance management software can be used to verify regulatory requirements in standards such as ISO, OHSAS, BRC, IFS or FDA (Bagadia, 2006). One of the most mentioned requirements is associated to equipment condition but ensuring compliance with legislation in force may also be related to safety and security, resulting for example in more reliable production or less injuries (Kans, 2013), and may also have impact on environmental control (Cato and Mobley (2001)).

Improved image of the maintenance area and the company

Improving the image in the maintenance area is related to the performance of maintenance and, of course, to obtaining the benefits presented in this dissertation.

When analysing the customer component, both in an intra-organisational perspective and in an end-customer perspective, Wireman (2005) defines three aspects that should be

considered regarding the image of the maintenance area or the company: the product or service attributes; the customer relationship; and the image and reputation. Maintenance has a direct impact on the quality of product and service, as well as on pricing model, according to its capacity to increase production and minimize costs. Regarding customer relationships, the maintenance area is entirely related to the delivery and response time. Looking at the case of manufacturing units, in certain business models it is imperative that there is no equipment downtime, otherwise the response time increases, the company image gets damaged and the customer dissatisfied. Thinking also of hospitality and remembering how easy it is nowadays for people to post reviews on social networks, forgotten complaints by guests can become a problem of credibility, image and potential loss of recurring revenue for hotels. These factors, combined with other variables such as safety, health or environmental awareness, have impact on the image and reputation of maintenance, and undoubtedly, the use of maintenance management software is an integral part of the solution to these problems.

Improved cost control

This benefit is invariably related to the purpose of the maintenance management software and to the justification of its use. Logically, organisations will only be able to realise that they increased or decreased costs, if they control costs. In maintenance, this control must be done rigorously, decisions must be made based on information, and it is in the context of this strict control that enters the maintenance management software.

Cato and Mobley (2001) refer to the software's ability to filter data at various levels (component, equipment, system, technical area or organisation) with detailed costs of man-hours, material, subcontracted services and other costs, that allows to, among other filters, separate by work order status or per type of maintenance. It is precisely the capacity of extracting information from the system, coupled with a maintenance strategy, that enables the maintenance area to take better decisions that result in increased capacity and reduced costs for the organisation.

Improved inventory control and reduced inventory costs

For many organisations, stock management can be seen as a key point for maintenance management. Different authors have presented possible problems of managing stock with a manual system and demonstrated how this management can be improved using a

maintenance management software (Bagadia, 2006; Cato and Mobley, 2001; O'Donoghue and Prendergast, 2004; Wienker et al., 2016). Some of the problems associated with manual stock management have to do with the difficulty in knowing the existence of materials, the excess or lack of materials, the existence of obsolete parts, duplicate items purchased from different suppliers, lack of information about substitute parts or little control over the materials that are issued from the storeroom. In fact, these problems can have a major impact on business, for example the lack of parts can cause the maintenance area to not be able to perform work that has been planned or, for example, to repair damaged equipment that is crucial for production.

The impact of maintenance management software in this area is indeed remarkable, with a computerised system the organisation can better control inventory, ensuring that parts are available, and employees are more productive, since they not only do not have to waste time searching parts, but also do not have to wait for the purchase of parts to carry out their work. The software also allows to guarantee the best stocking quantity for each spare part, and the system can even automatically order parts based on the minimum stock level defined for each part. This control allows the stock to be minimised, contributing to cost savings. Duplicate parts can be easily detected through the system, and the creation of a link between equipment and spare parts and the identification of obsolete parts also make management more efficient, avoiding manual verification. The record of the use of the spare parts in the work orders also allows a strict control of the store outputs.

Several authors have demonstrated the importance of managing stock through a computerised system for the maintenance area. Wienker et al. 2016 believe that within three years companies can reduce costs to 5% to 10% due to improvement in planning and inventory control. Cato and Mobley (2001) state that reductions of 20% are not unrealistic, setting an average between 5% and 12%. Bagadia (2006) holds the view that typical savings range between 10% and 15%. In a study of the implementation of maintenance management software applied to a textile company, O'Donoghue and Prendergast (2004) reported a cost reduction of £ 17,494 in spare parts, accounted for only 6 months after the introduction of the system in the company.

Reduced energy consumption

As Wireman (2005) states, well-maintained equipment generates reductions in energy consumption between 5 and 11 percent compared to poorly maintained equipment. Cabral (2017) argues that the collection of information on the overall energy consumption of the facility is essential and that an individual assessment of the energy of some equipment and systems should also be made in order to find opportunities for improvement.

According to Cabral (2017), although it is not the sole responsibility of maintenance, maintenance personnel can play an important role in detecting some factors that impact on energy consumption, namely: verification/calibration of sensors to prevent incorrect data; improvements in insulation, design and equipment to prevent heat loss; elimination of vapours, heated or cooled water and compressed air leaks; improvements in lubrication; prior detection of poor bearing condition; recommendations for the detection of poor conditions related to waste of energy; or recommendations for improvements in design.

A maintenance management software can be used to record energy consumption (Cato and Mobley, 2001, and it can also be used to schedule a set of actions aimed at fulfilling some of the factors mentioned above, contributing to a reduction of costs through an adequate energy consumption.

2.2.4. Important Aspects in Choosing a Maintenance Management Software

Before starting the selection process of the maintenance management software, it is necessary that the project is justified, and according to Bagadia (2006), so that the purchase of a CMMS makes sense, the organisation should reflect and understand if it is able to answer questions such as:

- What is the cost for the company to have operations or production stopped due to lack of monitoring of the spare parts needed for the interventions?
- What costs is the company having the most compared to previous years?
- Does the organisation have enough information to plan maintenance interventions?
- Is information available when it is needed?

The answers to questions such as those listed above, coupled with other factors, help organisations to determine whether they need to have a CMMS.

The choice of maintenance management software is not the main focus of the dissertation, but important aspects in the selection process should be highlighted such as the ease of implementation, training provided by the consultancy company, software features, integration with other software, reputation of the software and the consultancy company, price, user-friendly software or the availability of local support, which are widely mentioned in the literature (Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001), either in the area of maintenance and in the context of generic IT implementations.

2.2.5. Future

A considerable literature has grown up around the future of maintenance and the development of new applications for maintenance that commonly address topics such as E-maintenance, Predictive Maintenance, IoT (Internet of Things), Machine Learning or Augmented Reality.

In fact, by checking the applicability of some of these technologies, such as automatic sensors that collect and emit different data of industrial equipment, fleets of vehicles or infrastructures, it is possible to anticipate several opportunities to benefit the maintenance area. In a study carried out in the Netherlands, Germany and Belgium, PwC and Mainnovation (2017) concluded that only 11% of companies are at level 4 of predictive maintenance, that is, they are in a mature state that allows predicting future failures of the equipment and applying the most effective preventive methods based on analytical techniques on big data about technical condition, usage, environment or maintenance history. The study points out that the existence of skilled people in areas such as reliability engineering and data science, the use of standard software tools and maintenance log are all very important in the predictive maintenance processes of companies that are in this state of maturity. The study also advocates that, in order to have more organisations reach this state, they should stimulate a digital culture to all employees, allowing more and more decisions to be made based on data.

In Portugal, PSE (2017) denotes that, regardless of the maturity state of the organisations, several investments have already been made in maintenance, but investments in management systems with alarm and supervisory systems, sensors, business intelligence

infrastructures and data analysis systems are still only associated with a limited set of more evolved companies.

Much could be said about the future of maintenance, but it is also important to note that the technology in maintenance should be applied in a progressive way, to allow companies in a less developed state to reach, in a sustainable way, a more advanced management and maintenance organisation. Kans (2013) recalls that for technology not to fail, people must understand the purpose of the use, not forgetting that technology must always be managed, maintained and linked to the organisation's strategy.

2.3. Benefits Management

The evolution of technology in recent years has forced organisations to become capable of managing the implementation of IT and ensure that technology contributes to the achievement of business goals. Ward and Daniel (2006) emphasise that managers should be responsible not only for IT investment decisions, but also for the presentation of benefits that justify investments, given the costs and risks involved in implementing IT as well as the organisational changes they imply.

As in other areas, IT investments in the maintenance area must be justified. Kans (2012) highlights the importance of proving the impact of IT investments in maintenance by assessing the benefits in financial measures but reveals that there is some difficulty in this field, even though maintenance managers are satisfied with IT investments and are aware of the benefits that come from it.

According to Ward and Daniel (2006), benefits can be either tangible or intangible. Tangible benefits are designated as benefits that can be measured by a quantifiable objective and usually through a financial measure. Intangible benefits are considered subjective and tend to employ qualitative measures. As described in detail in Section 2.3.1.2., benefits can also be classified in four categories: financial, quantifiable, measurable and observable.

Several approaches have been developed to ensure the success of IT implementations in organisations. Ward and Daniel (2006) argue that IT investment is consummated in delivering performance improvements to the organisation, and for that to happen, there should be a benefits management process, together with other important approaches such as: IS/IT Strategic Planning, Systems Development, Project Management, Investment Appraisal and Evaluation, Change Management, Risk Assessment Techniques and Risk Management Processes.

Ward and Daniel (2006) define benefits management as a process that aims to make the potential benefits resulting from the use of IT be effectively realised. Benefits management, a concept that began to be developed in the 1990s by consultancy firms and business schools (Breese et al., 2015), enables managers not only to make decisions on the progress or abandonment of certain investments, but also to organise and better

manage the benefits these investments bring to the organisation throughout the project life cycle.

There are many principles sustaining the creation of value that results from the use of IT. The literature on benefits management (Doherty et al., 2012; Peppard et al., 2007) establishes some considerations about the way IT projects proceed and the vision of the benefits management approach:

- IT does not have intrinsic value - Acquiring technology by itself does not confer any benefits. The value of technology is not in its possession but in the benefits obtained by the organisation through its effective use.

- Benefits arise when IT enables people to do things differently - To improve the way information is used, processes are redesigned or new forms of work emerge. The benefits emerge whenever people are more efficient or effective performing their roles.

- Only managers and users can deliver benefits - The benefits emerge from changes and innovations in the way of working, so that only managers and users can promote them, and the IT department should not be the responsible for realising the benefits. If these responsibilities are aligned, the involvement of business staff in IT projects tend to be higher.

- All IT projects have outcomes, but not all outcomes are benefits - The challenge is to avoid negative outcomes and ensure that positive outcomes deliver real benefits.

- Benefits realisation is an ongoing journey and not a destination - The fact that the IT project is delivered on time, according to the specification and within budget, does not mean that benefits are realised. In most cases, benefits only occur after a long period of time, and therefore they should be monitored, evaluated and continuously reviewed.

2.3.1. Cranfield Benefits Management Model

Several benefits management models have been proposed in the literature, to help organisations to identify, monitor and realise benefits from their IT projects (Braun et al.,

2009). However, this section focuses on the Cranfield Benefits Management Model (Ward and Daniel, 2006), which resulted from an extended research programme initiated in the mid-1990s at Cranfield School of Management, and that is one of the most used models. The model has been optimised over time through research carried out and experience from the use of this method by some organisations. The process, which includes some of the ideas of TQM (Total Quality Management) and other methods such as Six Sigma, consists of various activities of planning and implementation of IT projects that are designed to allow an assessment of the costs involved and ensure that benefits are achieved. It is also important to note that this model is not limited only to IT projects, it can be used for other change initiatives in organisations, knowing however that it is increasingly common for IT to be an integral part of these processes.

2.3.1.1 Process Model for Benefits Management

Ward and Daniel (2006) describe the process of benefits management through a cycle consisting of 5 steps, as described above.

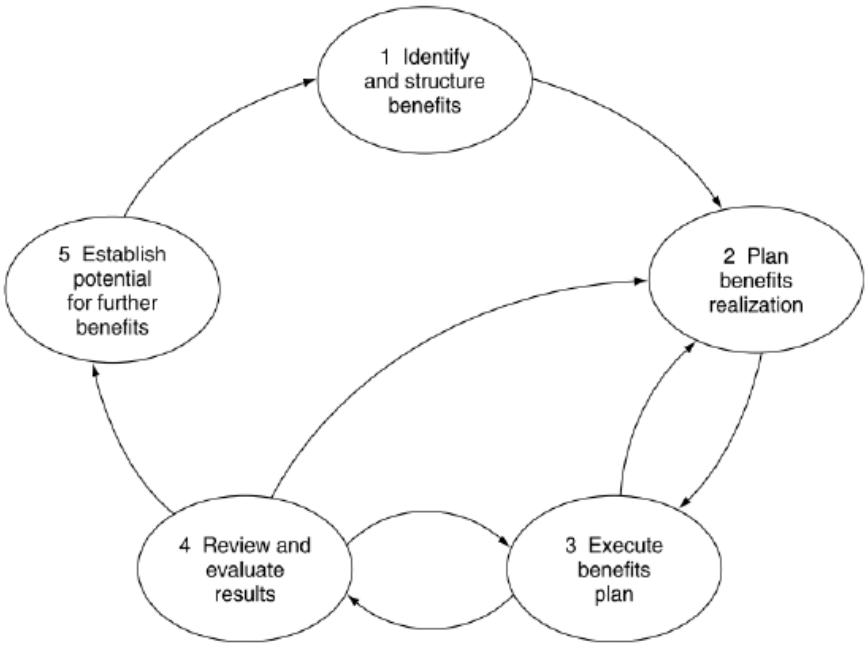


Figure 3 Benefits management process model (Ward and Daniel, 2006)

Stage 1 - Identification and structuring of benefits: The phase of identification and structuring of benefits consists in the definition of the objectives of investment, objectives that are related to the drivers for change. All the potential benefits and the metrics that

will be used to prove these gains are identified, as well as the person responsible for each benefit. One of the exercises that should be done at this stage is to realise how IT functionality and changes may cause the benefits to be achieved. At this stage, the implications for stakeholders should also be identified, including those that may threaten the success of the project, as well as the changes required at the organisational level.

Stage 2 - Planning of benefits realisation: The purpose of this stage is to produce a benefits plan and a business case that allows to decide the approval of the project. For this, each benefit should be clearly agreed and described, its respective measures, the changes, the necessary resources, as well as the times these benefits are expected and, whenever possible, with an expectation materialised in value. The roles and responsibilities should be agreed with the different stakeholders. Ward and Daniel (2006) recommend producing the Benefits Dependency Network (Figure 4), a scheme that is specifically intended to document and demonstrate how benefits are realised and which are the change relationships involved.

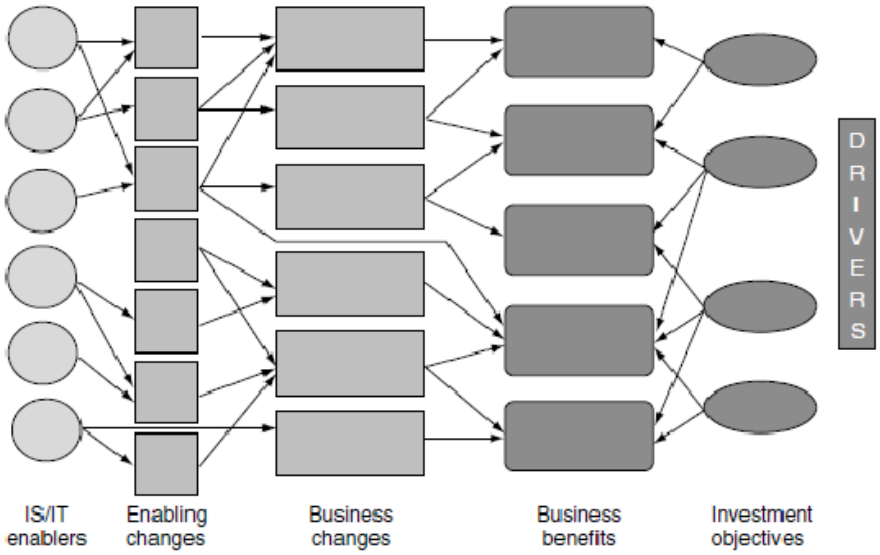


Figure 4 The benefits dependency network (Ward and Daniel, 2006)

Stage 3 - Implementation of benefits realisation plan: The objective of this phase is to ensure that the planned actions actually take place as planned, possibly with milestones for greater control and monitoring of the project. The implementation of the benefits plan requires attention to the change program, the IT implementation, as well as the deliverables of benefits plan.

Stage 4 - Review and evaluation of results: The IS/IT investments should be evaluated after completion. In the review and evaluation of benefits, benefits achieved and those who have not been achieved should be identified, and understand if there is any action that allows them to be achieve. It is also important to realise why some benefits have not been achieved, and to identify improvement opportunities for other projects regarding benefits management.

Stage 5 - Establishment of potential for future benefits: Once the project is completed, an analysis can be made to understand what other benefits might happen. It is an imaginative process, similar to the first stage, where opportunities to obtain benefits can be identified, either through new investments or changes in processes that have already been established.

2.3.1.2 Business Case

At the time of investing in an IT project it is generally easier to calculate the estimated costs than to predict and justify the benefits that organisation will have. It is in this context that the business case arises, a way of deciding if the investment will be made and that takes into account not only the variables value and cost of the investment, but also the process that is necessary to ensure that the project is completed with success. In line with the technical requirements in terms of IT infrastructure, the business case must contain the activities and resources that are necessary for the project, and it should be clear the contribution of IT to the improvement or creation of new capabilities (Ross and Beath, 2002).

Compared to other traditional methods, the business case from the perspective of the benefits management approach has a continued focus on the link between the change and benefit, the relevance of the role of those responsible for the benefits and the importance of benefit measurement (Ward and Daniel, 2006).

In order to measure benefits, it is important to understand how benefits can be achieved, and therefore, Ward and Daniel (2006) determine the existence of three possible causes for the rise of benefits: stop doing things that are no longer needed; do things better in activities that cannot be stopped; and do new things.

Ward and Daniel (2006) also developed a matrix that allows the classification of the benefits according to their degree of explicitness: observable, measurable, quantifiable, and financial. These four levels, described below, are based on the ability to assign a value to the benefit, according to current knowledge, regarding the benefit expected in the future.

Observable benefits

An observable benefit is assessed by certain criteria based on judgment or opinion of specific individuals to determine the extent the benefit will be realised. This type of benefit is commonly associated with subjective or qualitative benefits such as increased employee enthusiasm or customer satisfaction, which as Ward and Daniel (2006) state, sometimes can only be measured by perception.

Measurable benefits

Measurable benefits are benefits that are already being measured or that can easily be associated with a metric to be put into practice. However, it is not possible to quantify how much performance will increase when changes are effected.

Quantifiable benefits

Quantifiable benefits may be defined as benefits whose improvement based on the outcome of the changes is reliably quantified. One of the major differences compared to measurable benefits is that for quantifiable benefits there is a measure prior to the implementation of the change that allows calculating the benefit generated.

Financial benefits

Benefits that are quantified and for which gains in value can be measured by applying a financial formula such as cost or price are designated as financial benefits.

3. Methodology

As previously stated, the main purpose of this dissertation is to understand what are the benefits of maintenance management software for Portuguese companies. Therefore, three main objectives were established: a) understand if organisations are measuring the benefits and assessing the level of improvement that comes from the use of maintenance management software; b) identify the benefits; and c) assess whether organisations that have implemented this type of software consider the project as successful.

In this section, the methodology followed in this dissertation is explained and the way in which the objectives of the dissertation are addressed are also clarified. The population and the sample of this study are also identified, as well as the methods used to collect and analyse data.

3.1. Literature Review

Diverse secondary data was collected in order to better understand the existing literature on the subject in question. A conceptual approach is made to clarify general definitions of maintenance, as well as aspects that are specific to the maintenance management software. The last part of the literature review focuses on the planning and evaluation of IT investments, and more specifically on the benefits management approach.

As mentioned before, there are few practical studies that indicate the true benefits of using maintenance management software, and this fact, together with the lack of data in the Portuguese market, contributes to the justification of this study.

3.2. Questionnaire

In order to obtain representative market data, a questionnaire (Annex II) was applied to the Portuguese market, to companies that have a maintenance management software.

The selection criteria for the benefits included in the questionnaire was based on the importance and the range of benefits considering the population of the study, and according to the literature review, contacts made with the industry and with the professional experience of the author. It is also important to highlight the suggestions for

improvement pointed out by entities that were contacted in the scope of this study, namely Rodrigo Cabral and Alexandre Veríssimo, Partners of Navaltik Management, and Eng. José Paulo Saraiva Cabral. After completing the questionnaire design, it was validated with the President of APMI, Eng. Armando Ferreira Augusto, and a pre-test was carried out to verify the applicability of the questions with one of the companies participating in the questionnaire.

The structure of the questionnaire is presented in full in Annex II, being composed of 16 questions divided into 6 sections. The first section consists of only one question, with the purpose of verifying whether or not the company has a maintenance management software, and, if not, to make the answer unfeasible. The second section has questions related to the characteristics of the software that the company owns and with the features used. In the third section, questions were designed to understand the important factors for the success of the project of maintenance management software, and to verify if companies consider the project as being successful. The questions of the fourth section are directly related to the main objectives of the research, focusing on the problems of maintenance management, the benefits of using maintenance management software and the maintenance indicators used by companies. The fifth section is composed of two questions related to the decision of purchasing a maintenance management software. Finally, the sixth section consists of characterisation questions about the respondent and the company.

The questionnaire is composed mainly by closed questions to guide respondents and simplify the statistical analysis of the questions. Some of the questions also accepted further comments with the objective of allowing the validation of the available options and obtaining qualitative information.

As regards the research question, the questions included in sections 3 and 4 of the questionnaire aim to respond in a concrete way to the objectives of the research. The questions 6 and 7 allow a concrete assessment of the success of the maintenance management software project, question 9 allows identification of the real benefits of using the software, while questions 8, 9 and 10 focus on how organisations assess the level of improvement they obtain from the use of software. Complementary to the research objectives, the questionnaire seeks to examine the perceptions of users of maintenance management software, representing a marketing research approach that aims to answer

the objectives that were established based on the motivation of the author. Specifically, questions 4, 5 and 12 of the questionnaire allow analysis of, respectively, the most used features of the software, most important factors to the success of the software and the most important aspects for the purchase decision of the software.

3.3. Population and Sample

According to Malhotra (2007), the target population is the total of elements that share a set of characteristics and from which information is sought to infer. The population of this study consists of Portuguese organisations using maintenance management software.

The sample must be representative of the population under study, and therefore the sampling process must be analysed and weighted by several factors (Maroco, 2007). As mentioned by Malhotra (2007), the researcher sampling technique chosen can be either non-probabilistic or probabilistic. It is considered probabilistic sampling when each element of the population has a known and equal probability of being selected. However, due to time and resource constraints, a non-probabilistic sampling for convenience was used for this study.

The questionnaire was developed in the platform Google Forms and was available online between February 14th and March 28th, 2018. A single response was requested per company, from the person responsible for the project of maintenance management software. The questionnaire was disseminated via e-mail and through contact with companies on the social network LinkedIn, and an anonymous response was required.

3.4. Data analysis

For the statistical treatment of the data, the software IBM SPSS Statistics (Statistical Package for the Social Sciences) version 24 and Microsoft Excel were used. The analysis of the data collected from the questionnaire was elaborated using descriptive techniques.

Since this study is intended for organisations, the characterisation of the sample is made considering not only the profile of the respondents but also the profile of the companies they represent. The general characteristics of the organisations are described, namely the business sector and size of the maintenance area, as well as the characteristics of respondents regarding their role in the company and years of professional experience.

After the characterisation of the sample, aspects related to the use of maintenance management software by organisations are analysed such as the maintenance management software used, years of use of the software and the features used. Prior to the reflection about the success of maintenance management software projects, measurement of benefits resulting from the use of maintenance is described, analysing the benefits obtained, the common problems in maintenance and the performance indicators used. Finally, aspects related to decision-making of maintenance software projects are presented.

4. Results and Discussion

This section aims to present the results of the quantitative study resulting from the statistical analysis of the information gathered through the application of the questionnaire.

4.1. Characterization of the Sample

A total of 104 questionnaire replies were received, but 97 usable questionnaires were counted, after excluding those who could not answer the complete questionnaire because the company did not have a maintenance management software. Given that the questionnaire was disclosed to 290 companies, a response rate of 35,86% was obtained.

4.1.1. Business sector

Regarding the business sector, a large diversity of companies is represented in this study (e.g. Manufacturing, Transportation, Facilities, Energy, Healthcare), a positive aspect since the conclusions reached for the sample may be considered comprehensive.

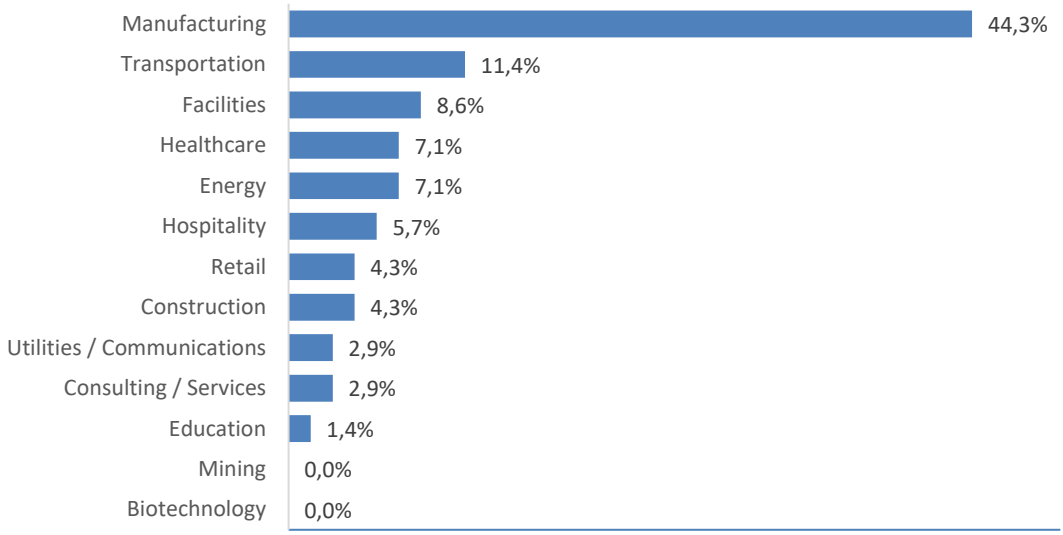


Figure 5 Distribution of companies per business sector

It should be noted that the companies in this study are mainly manufacturing companies. As can be observed in Figure 5 (see Annex III – Table 1) which represents the distribution of companies by business sector and does not include the 27 companies that selected the option "Other" in the questionnaire, out of the 70 companies that indicated one of the

suggested sectors, 44,3% are manufacturing companies. This dominance in the number of participating companies belonging to the manufacturing sector might be considered expected in some way, considering the importance that maintenance has for production and the impact that the use of maintenance management software can have in this type of business.

It should also be observed that none of the companies participating in the study belongs to mining or biotechnology sectors.

The 27 companies that did not choose any of the business sectors suggested in the questionnaire, selected the option "Other" and indicated the sector to which they belong in an open response field, constituting a list that includes the following sectors: aircraft maintenance; automotive; banking; ceramics; chemicals; electronics; environment; food; glass; HVAC; manufacture of metal and plastic packaging and filling; port activity; printing and graphic art; research; ship maintenance; ship repair and construction; shipyard; textiles; warehousing; waste; and wood and furniture. Given the number of companies that selected the option "Other" and that could be represented in only one sector, it might have been recommended to include other answer options in the questionnaire. For instance, there were 3 companies that answered “Oher” and indicated navy industry as sector. Likewise, 3 companies selected “Other” and specified sectors that are related to environment and that could have been included in a single sector. In addition, some of the firms indicated as “Other” could have been framed in the sectors that were suggested in the questionnaire, but the choice made by the respondents of selecting “Other” and distinguish the sector could also reveal that there was a need to have more specific sectors.

4.1.2. Size of the maintenance area

Most of the companies included in the study have a considerable maintenance structure, with 40,2% of the companies having more than 26 employees in the maintenance area and for 25,8% of the companies the number of employees varies between 11 and 25 people. The Figure 6 (see Annex III – Table 2), presented below shows the information regarding size of maintenance area of the organisations.

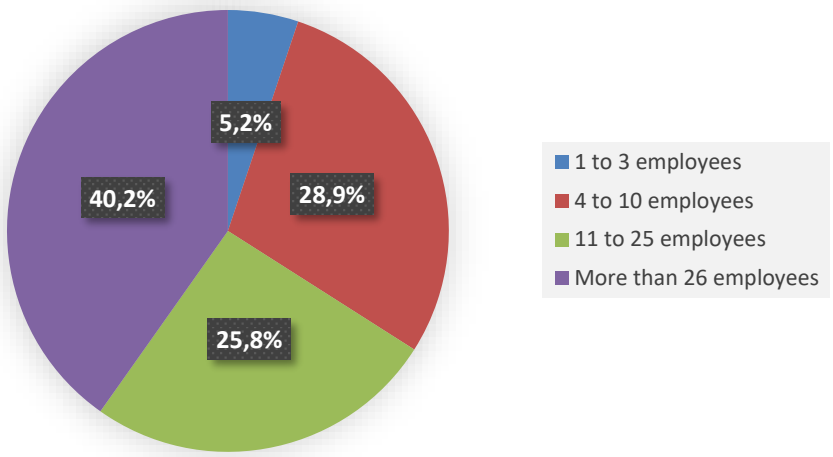


Figure 6 Distribution of companies per size of the maintenance area

The low percentage of companies participating in the study with a maintenance area ranging from 1 to 3 people (5,2%) may indicate that, in principle, smaller companies or companies that have a reduced maintenance area are less likely to use a software to support the management of maintenance.

4.1.3. Position in the Company

Regarding the position of the respondents in their companies, 87 responses were considered, based on the suggestions of functional areas that were included in the questionnaire (see Annex III – Table 3). There were 10 respondents that indicated the option "Other" and are not represented in Table 3.

The vast majority of respondents belong to the maintenance area (88,5%, N = 77), as would be expected given the specificity of the subject of this inquiry. The questionnaire was also answered by four managing directors (4,6%), three respondents from IT (3,4%), two from Production (2,3%) and one from Quality area (1,1%).

4.1.4. Years of professional experience

From the Figure 7 (see Annex III – Table 4) presented below with the distribution of respondents per years of professional experience, we observe that 11,3% had between 2 years and 5 years of professional experience, 12,4% had between 6 years and 10 years of experience, and 76,3% of them are professionals with more than 11 years of experience.

These data indicate that, in general, the responsibility for the project of maintenance management software in organisations is attributed to people who already have extensive years of experience.

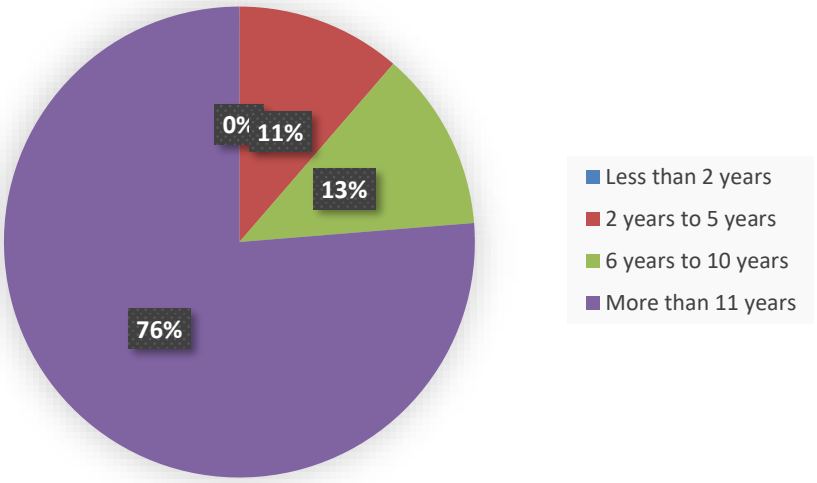


Figure 7 Distribution of respondents per years of professional experience

4.2. Maintenance management software

This section describes and discusses three key aspects related to the use of maintenance management software by companies participating in the study: the system in the place, the years of use and the features used.

4.2.1. Product

Concerning the product, 79 companies answered the optional question 'What maintenance management software is used in your company?', 3 of whom were not considered because indicated that use more than one maintenance management software. For this reason, only 76 companies using a single maintenance management software are considered for the analysis of the product used, as can be seen in Annex III - Table 5.

Of these 76 companies, over half indicated that use Product A (63,2%). The Product B is used by 9,2% of the companies, the Product C by 3,9%, and the other companies use other systems, which are divided among 14 different products.

4.2.2. Years of use

The results indicate 12,4% of the organisations have been using a maintenance software for less than 2 years, 22,7% for 2 to 5 years, 34% for 6 to 10 years and 30,9% for more than 11 years (see Annex III – Table 6).

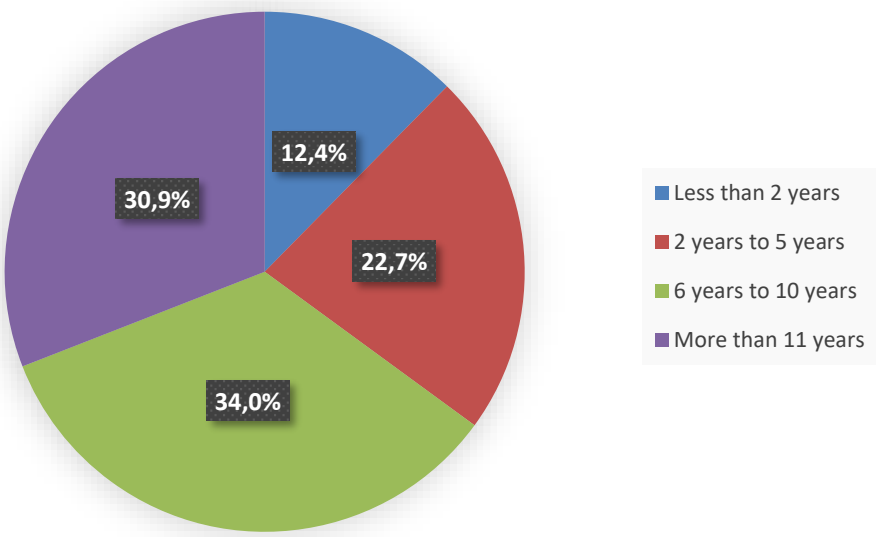


Figure 8 Distribution of companies per years of use of maintenance management software

When analysing the data regarding the years of use of the software, it is important to bear in mind the observation made by Cabral (2013) that indicates that the transition from an organisation driven by reactive changes to an organisation of the highest level can take between 3 to 5 years. This is an important fact, since for 64,9% of the companies included in the study use the software for at least 6 years, which may mean that the project of the maintenance management software is seen by most companies as a medium-long term investment.

4.2.3. Features

The functionalities of maintenance management software that are used by organisations are shown in Figure 9 (see Annex III – Table 7). The two features that are most used are Planning and scheduling of preventive maintenance and Planning and scheduling of work orders, both of which have the same percentage of use by companies (92,8%). It is important to point out that, as Wireman (2005) mentions, the practice of preventive maintenance is indispensable for the maintenance area to focus on optimisation.

The third most commonly used feature is Equipment failure history which is used by 85,6% of the organisations. This high percentage of use might be explained by the importance that this feature has for maintenance management. For instance, checking the failure history of equipment allows to verify what has been done in the past to repair a failure that has come up again, check for recurring failures and see if any improvement can be made to avoid future failures or even consider the replacement with new equipment.

Maintenance requests management is the fourth most used feature, with 83,5% of companies indicating that companies use the software as a way of reporting failures and communicating with the maintenance area.

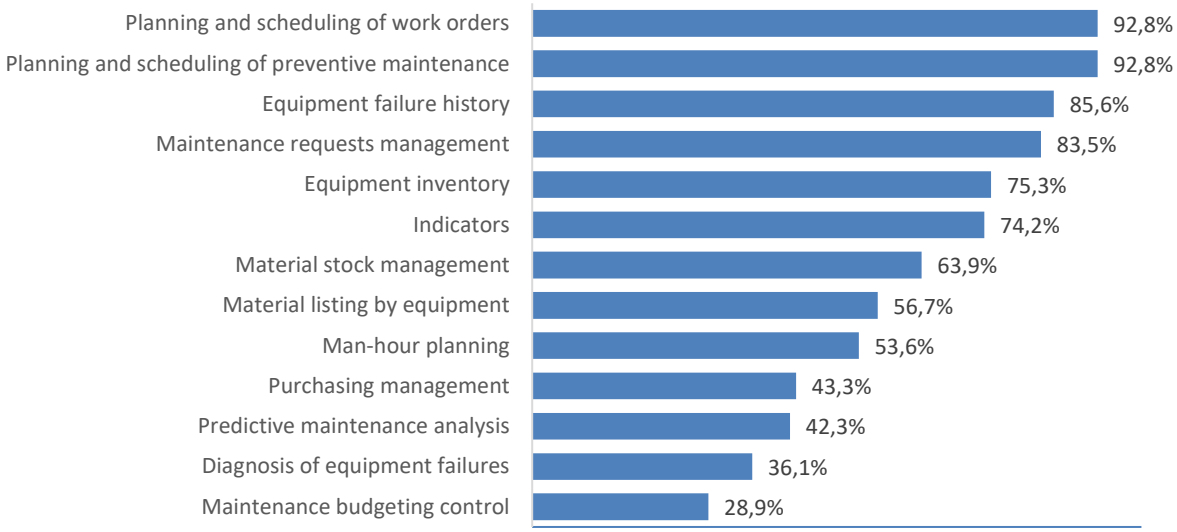


Figure 9 Features of maintenance management software used by companies

Surprisingly, the feature Equipment inventory is indicated as being used by only 75,3% of the companies, appearing as the fifth most used functionality. In fact, any company using a maintenance management software should have an inventory of equipment, so there may have been poor interpretation of the respondents or poor explanation of the author regarding this response option. Possibly other terms could have been used to help explain the option better, such as equipment/asset listing.

The data shows that most companies (74,2%) use maintenance indicators. However, considering that almost a quarter of companies do not use indicators, it would be

interesting to understand through further research why these 25 companies do not use indicators.

Material stock management (63,9%), Material listing by equipment (56,7%) and Man-hour planning (53,6%) are other features that are also used by companies and which have considerable percentages of use.

The least used features are Purchasing management (43,3%), Predictive maintenance analysis (42,3%), Diagnosis of equipment failures (36,1%) and Maintenance budgeting control (28,9%). It is interesting to note that predictive maintenance analysis is used by 42,3% of Portuguese organisations, a figure that is significantly different from the 11% indicated in the study by PwC and Mainnovation (2017).

4.3. Measurement of benefits resulting from the use of maintenance management software

One of the questions included in the questionnaire developed in the scope of this work is directly related to the main objectives of this dissertation, with the purpose of evaluating the benefits that organisations obtain through the use of maintenance management software and determining the degree of explicitness of these benefits. The question is based on the benefits already identified in the literature review and was built having in mind the possibility of verifying if, in fact, companies accomplish these benefits and to analyse the level that is reached in each benefit. As previously mentioned, the benefits listed in the questionnaire are those that were considered more important and more comprehensive for most companies, but it is natural that other benefits could have been considered according to the specific context of each organisation.

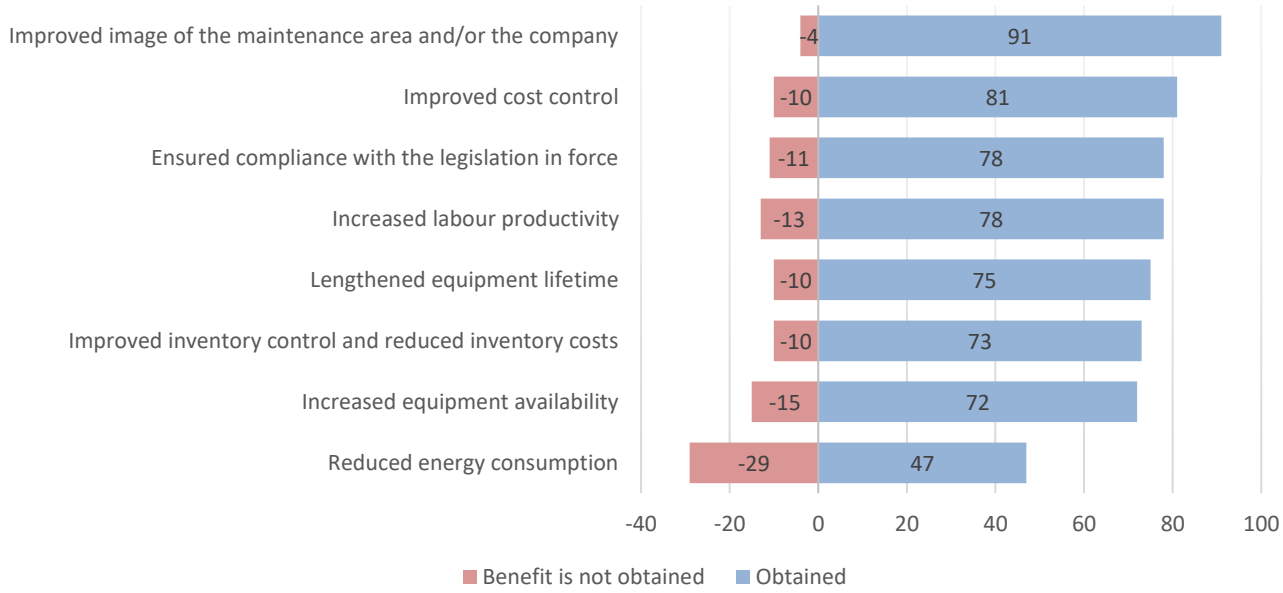


Figure 10 Benefits achieved by companies with the support of a maintenance management software

The Figure 10 illustrates, for each benefit, the balance between the companies that obtain the benefit and those that do not, excluding those who selected the option "Don't know / No answer".

It is confirmed that most organisations obtain the benefits that were listed based on criteria previously mentioned, being that, except for the benefit of energy consumption reduction, all benefits are obtained by at least 74,2% of the organisations participating in this study. Similarly, the study carried out by Plant Maintenance (2004) concluded that the implementation of maintenance management software allowed companies to obtain some or significant benefits.

In Figure 11 are represented the benefits obtained by companies according to the analysis of the four levels of each benefit that range from "Benefit is perceived", "Benefit can be measured", "Benefit is effectively measured" and "Benefit is Evaluated in value (€)", which correspond to four levels of explicitness defined by Ward and Daniel (2006), respectively, Observable, Measurable, Quantifiable and Financial.

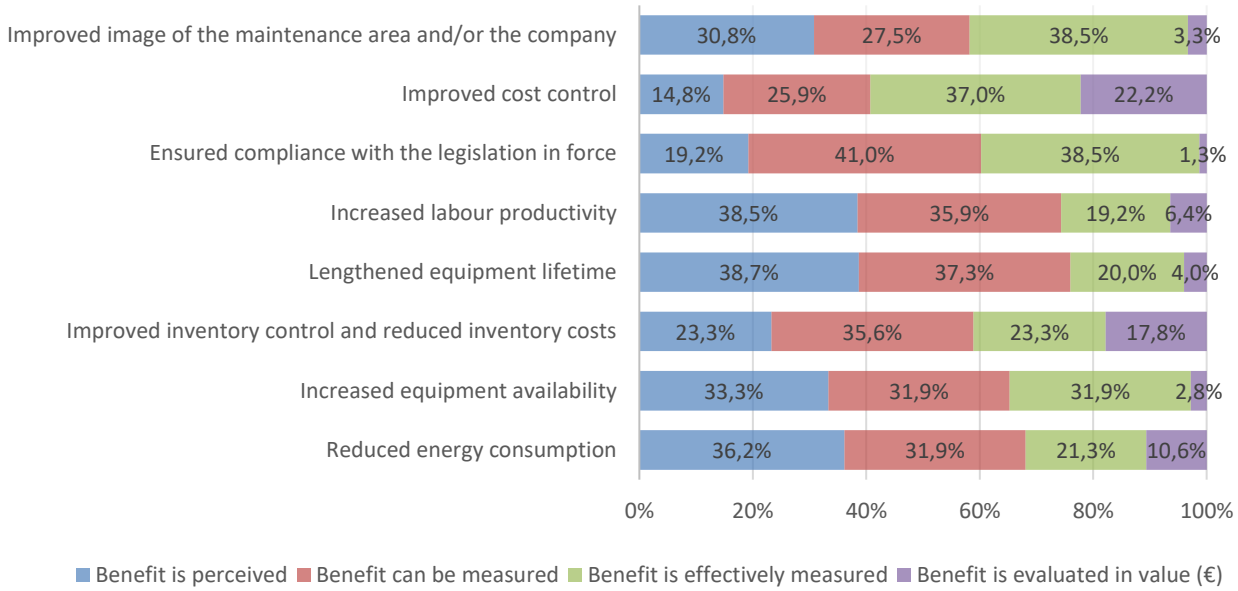


Figure 11 Level of benefits achieved by companies with the support of a maintenance management software

Improved image of the maintenance area and/or the company

Improving the image of the maintenance area is the benefit that is most obtained by the companies participating in the study, with 91 of the organisations responding to this question stating that they obtain this benefit and only 4 transmitting that they do not obtain the benefit. It is also a benefit that can be considered, in some cases, less tangible. Although it is possible to quantify financially the improvement in the image of the maintenance area, it is undeniable that there are other benefits more tangible than this, and the proof of this is that only 3 organisations claim to be able to evaluate this benefit in value.

Improved cost control

The improvement in cost control is also an expressive benefit, obtained by 81 out of 91 companies who answered this question. As mentioned in Section 2.2.3, this is a benefit of great importance, which is generated by the ability of organisations to make good decisions, based on equipment history. The fact that it is the benefit that more companies can translate into financial value (n=18), could mean that maintenance management software is perceived as a tool that allows to obtain the necessary data to make technical and economic decisions.

Ensured compliance with the legislation in force

With regard to the benefit ensured compliance with the legislation in force, it is obtained by 78 of the companies, which represents a considerable number of companies and might be considered expected considering the rigor and care that is required in an area such as maintenance.

It should be noted that only 1 organisation declares to be able to quantify this benefit in financial value. This may be due to the fact that most companies do not consider any financial losses that may result from non-compliance. Understanding how a system can improve procedures to demonstrate regulatory compliance, and accounting for financial losses that may result from failure to comply are key issues in understanding and evaluating the contribution that maintenance management software makes to comply with legislation.

Increased labour productivity

In terms of increased labour productivity, the data of the questionnaire demonstrates that 78 out of 90 companies increased the productivity of their employees. This benefit is mostly perceived, 30 companies perceive the benefit, 28 are able to measure it, 15 measure it effectively and 5 manage to assign a financial value to the benefit obtained.

It should be noted that among all organisations participating in this study, 92,8% reported that have a maintenance management system to put in practice preventive maintenance and plan maintenance technicians' work, 63,9% manage stock, 56,7% have a material listing by equipment and 53,6% plan man-hours, features of maintenance management software that are key to ensuring that labour is more productive compared to using manual methods.

Lengthened equipment lifetime

Another benefit that is gained by most companies is the lengthened equipment lifetime, with 75 out of 85 companies declaring that they get this benefit. This benefit can be generated through an effective preventive maintenance policy and as previously mentioned, 92,8% of the companies participating in this study show that they use maintenance management software for planning and scheduling of preventive maintenance. The data obtained from the questionnaire demonstrate that although many

companies get the benefit, only 4% of those companies attribute a financial value to the benefit.

Improved inventory control and reduced inventory costs

With respect to improved inventory control and reduced inventory costs, 73 organisations report that get the benefit, while 10 declare that do not. Almost 18% of organisations claiming benefits related to control of spare parts represent the benefit in a financial value. This value, which is high compared to the ratio of other benefits, demonstrates the importance of warehouse management for maintenance.

Increased equipment availability

In the case of the benefit increased equipment availability is obtained by 72 of the 87 (82,8%) companies that answered this question. This figure can be considered high when compared to the study of Plant Maintenance (2004) which reveals that the increased availability is obtained by 46,6% of the companies.

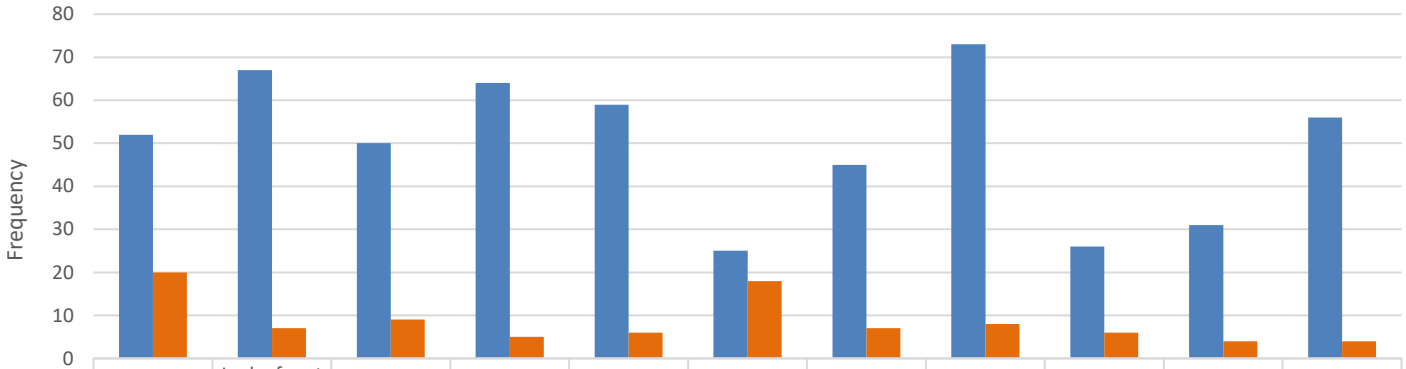
The high number of companies increasing equipment availability demonstrates the importance of this benefit, which can be critical for the production and operation of companies, and which in many cases represents a lot of value for organisations. It is therefore somewhat surprising that the questionnaire data reveal little translation in financial terms, with only 2 organisations declaring that calculate and represent the benefit in a financial variable.

Reduced energy consumption

Regarding the benefit reduced energy consumption, it is the least obtained by the companies participating in the study (n=47). Nevertheless, the fact that 10,6% of the companies that obtain the benefit are able to calculate a financial value could mean that some companies are keen to carefully assess the savings obtained by controlling energy consumption.

4.3.1. Problems in maintenance

The benefits obtained with the use of a maintenance management software are often associated with practices that solve common problems in the maintenance area. Given that the benefits of maintenance management software and problems in the maintenance area are related, a question was included in questionnaire to not only identify problems within organisations, but also to somehow do a double check some of the benefits identified by respondents. In Figure 12 the results of question 8 are shown, where the problems identified by the organisations before and after the implementation of the maintenance management software were pointed out.



	Excess of corrective maintenance	Lack of cost control and little accuracy in budget management	Lack of control over employees	Lack of information in decision making	Lack of preventive maintenance	Lack of manpower	Lack of materials and/or excess materials	Inefficient work planning	Low availability of equipment	Low productivity	Safety issues and nonconformities in audits
Before	52	67	50	64	59	25	45	73	26	31	56
After	20	7	9	5	6	18	7	8	6	4	4

Figure 12 Problems identified in maintenance before and after the implementation of maintenance management software

The data indicate that the number of companies that identify problems in maintenance management prior to the implementation of maintenance management software is noticeably higher than the number of companies that identify problems after software implementation. Although the implementation of maintenance management software should not be the only factor that solves the problems in the maintenance area, the values obtained in this study allow us to confirm the importance that maintenance management software assumes in solving problems in different areas of maintenance. It is also found that these results generally support the benefits identified above.

Also noteworthy is the data obtained in the variable "Lack of manpower", the problem where there is the greatest approximation between the values obtained for before and after software implementation occurs. This data could possibly be explained by the intention of the maintenance area to obtain more investment, that is, resources are still scarce and more people are needed to work in the maintenance area. In fact, we might also consider the hypothesis that respondents are aware that it is not the goal of IT to withdraw work from people, but rather to improve the way they work.

4.3.2. Maintenance indicators

To confirm the use and evaluate the metrics established by the organisations, question 10 of the questionnaire was prepared to allow respondents to select, from a predefined list, the maintenance indicators that are obtained with the support of maintenance management software. The results presented in Figure 13 (see Annex III – Table 8) show significant differences between the indicators included in the study, with percentages of use ranging from 11,3% to 67%.

The two indicators that emerge with the highest rate of utilisation are Cost of preventive maintenance vs total costs of maintenance, with 67% and Cost of preventive maintenance vs total costs of maintenance with 66%. The use of these two indicators might be linked to the use of software features related to preventive maintenance and corrective maintenance. In fact, the planning and scheduling of preventive maintenance and the planning and scheduling of work orders are the most used features by organisations, both with the use rate of 92,8%. It is also important to note that these two indicators might be

considered when determining the benefits associated with equipment availability, cost control, equipment lifetime or labour productivity.

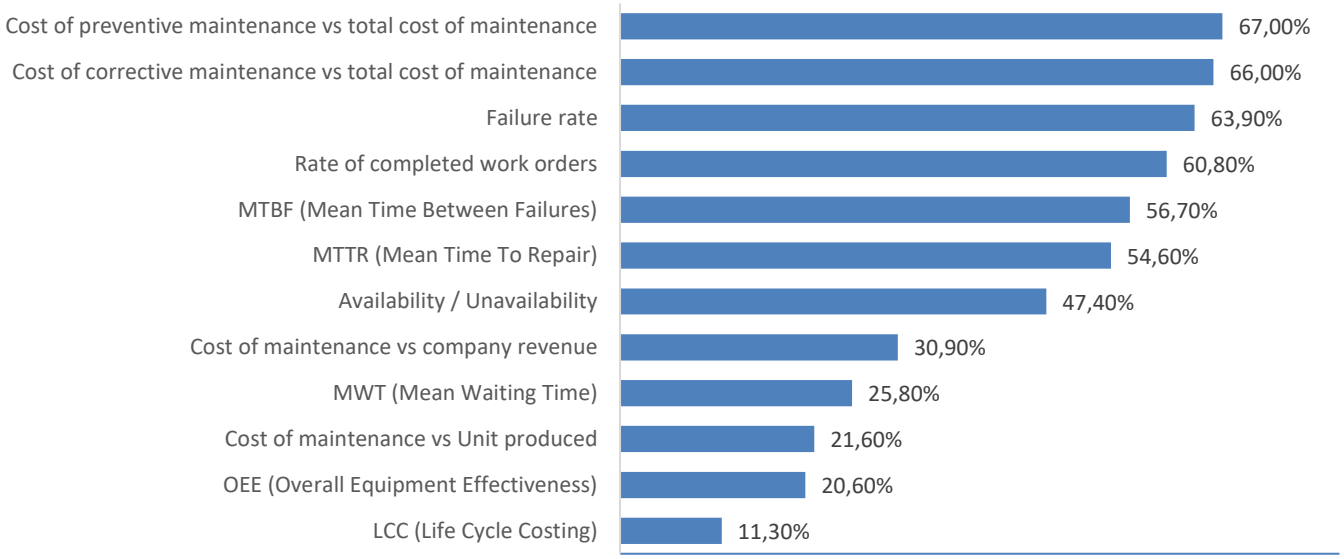


Figure 13 Indicators used and obtained with the support of the maintenance management software

Regarding the failure rate, it appears as the third feature most used by organisations. The indicator, which reflects the number of failures occurring in a given equipment per unit of use (Cabral, 2013), is used by 63,9% of the companies participating in the study.

The rate of completed work orders is an indicator used by 60,8% of organisations. This is an organisational indicator (CEN, 2007b), important as it allows the assessment of compliance with planned maintenance interventions within a defined time period.

Among all organisations participating in the study, 56,7% reported that extract MTBF from the system. MTBF is a good indicator of reliability of equipment or systems which expresses the mean time between failures, and it is desirable to have the highest possible value.

Just over half the organisations (54,6%) obtain MTTR, an indicator that represents the average time it takes to perform the repair after failure.

Regarding the Availability/Unavailability indicator, it is used by 47,4% of organisations. Interestingly, there seems to be a difference between this utilisation rate of this indicator and the benefit increased equipment availability that is obtained by 72 of 87 organisations

(82.76%). This difference can be partly explained by the fact that this benefit is recognised as an observable benefit by 33,3% of the companies that indicated the benefit, and in the case of observable benefits there are not metrics in place beyond perception.

The indicator Cost of maintenance vs company is an indicator that allows to contextualise the maintenance function as an integral part of the organisation. The fact that it is an indicator obtained by only 30,9% of organisations may mean that there is still room for improvement in the evaluation of maintenance and its relationship with the organisation's strategy.

The MWT indicator is used by 25,8% of the companies. This indicator represents the average response time of the maintenance area to attend repair requests and is therefore linked to the maintenance requests feature. Comparing the companies that use this indicator (25,8%) with the companies that use the maintenance requests feature (83,5%), it can be observed that although the resource is widely used to report failures to the maintenance area, most organisations do not have an established metric to evaluate the response time of the maintenance team.

With respect to Cost of maintenance vs Unit produced, it is obtained by 21,6% of organisations. This indicator contributes to the company's accurate understanding of the costs involved with the product and can therefore be considered an important management indicator. It is important to note that possibly the percentage of use of this indicator would be higher if only companies with production were considered, since service companies were also included in the sample.

The OEE is an indicator based on three aspects: availability, performance and quality. Although it is a widely-recognised indicator, which allows to evaluate the efficiency of processes and identify opportunities for improvement, it is an indicator whose calculation may be dependent on data from different departments of the organisation. Perhaps because it is difficult to obtain or because it is an indicator that is not centralised in the maintenance area, only 20,6% of organisations claim to obtain this indicator from the maintenance management software.

The least used indicator by the organisations is the LCC (11,3%). This is an important metric, as it relates to obtaining costs throughout the life cycle of the equipment and

allows the maintenance area to make the best decision between repairing or purchasing equipment.

It should also be mentioned that 4,1% of the respondents indicated that they use other maintenance indicators apart from those that were indicated as a response option in this question. The fact that the number of respondents indicating other options is relatively low might allow us to conclude that the response options given to the respondents are in line with the reality of the maintenance area and were assertive, in the sense that they cover most of the indicators used by companies.

4.4. Success of maintenance management software projects

One of the objectives of this study is to analyse the success of the maintenance management project not only in the context of the maintenance area but also from an organisational perspective. As can be observed in Table 9 (see Annex III – Table 9), a very large majority of the respondents (81,4%) report that the project of maintenance management software is seen as successful in their companies, making clear that the importance of this type of software is perceived and it is widely accepted by organisations.

It should be noted that 40 of the 97 respondents who work in a company using maintenance management software claim to have a defined criterion to measure the success of the project. Among companies that apply more specific criteria and companies that apply broader criteria, it can be said that the success of the project is determined by factors that, in general, are related to the level of use of the software or certain functionalities, implementation of procedures, user feedback, product characteristics, reliability of the data obtained, evidence of compliance with legal or certification requirements and, of course, the benefits obtained.

Only a small number of organisations (12,4%) do not see the project of maintenance management software as successful. There are 2 respondents who indicate that the success of the software project has no relevance and 4 respondents indicate that they do not know or preferred not to answer the question.

It is important to emphasise that the projects of maintenance management software are generally seen as successful in organisations, similarly to other studies that have been exposed by Plant Maintenance (2004) or Kans (2012). Nevertheless, it is important to

reflect in cases where projects are not successful, perhaps due to reasons that were previously mentioned such as failure to deliver the expected benefits of the project or due to incomplete use of the system.

Within the questionnaire, the respondents were also asked to indicate, without prioritising, the three factors that they consider most important to assure the success of the project of maintenance management software. In Figure 14 (see Annex III – Table 10), it is possible to observe the results obtained in the questionnaire for each of the suggested response options: disciplined and continuous compliance with procedures; buy-in from top management; existence of a manual of procedures with well-defined tasks and responsibilities; experience and technical support provided by the software consultancy company; focus on project benefits; adequate training; change management and appropriate new procedures; appropriate software; and user-friendly software.

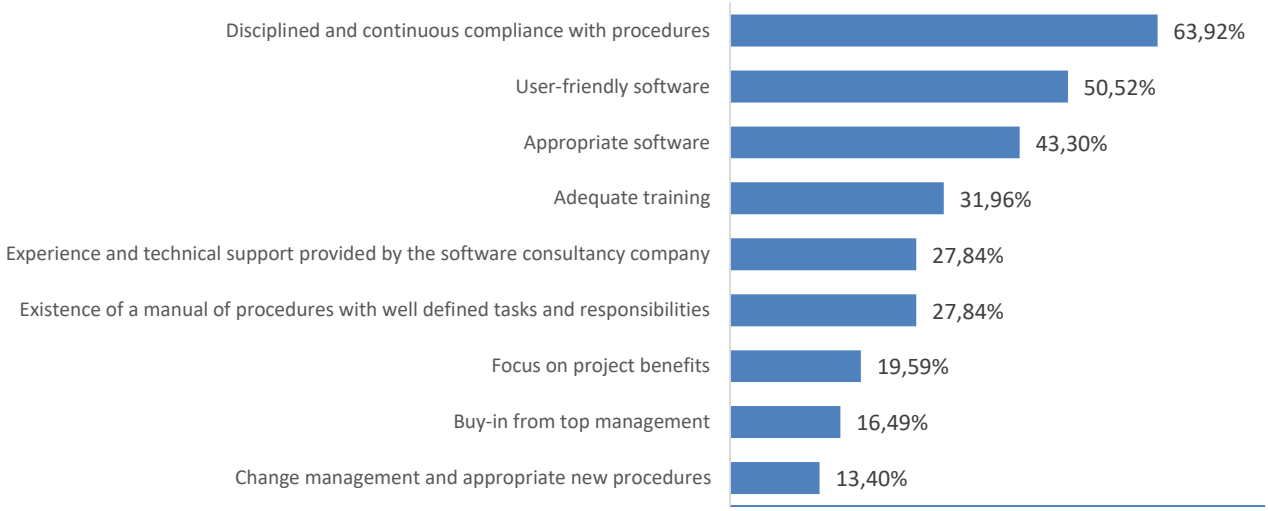


Figure 14 Critical factors for the success of maintenance management software

The three factors considered most important by the respondents were disciplined and continuous compliance with procedures, user-friendly software and the appropriate software, representing, respectively, 63,92%, 50,52% and 43,30% of respondents' choices.

It should be noted that disciplined and continuous compliance with procedures has been considered the most important factor, reinforcing the idea that people have a key role in

implementation, and that projects only work if there is in fact ongoing attention to compliance with established procedures.

Aspects related to the software, the fact that it is user-friendly and appropriate for the organisation, are also seen by the participants in this study as being some of the most important factors for the success of the project, similar to the conclusions obtained in the Plant Maintenance study (2004). Interestingly, this study from Plant Maintenance (2004) points out the commitment from senior management as the most important factor in implementation success, while the results of the questionnaire of this dissertation indicate that only 16,49% of Portuguese organisations consider the buy-in from top management as one of the most critical factors.

The factors adequate training, experience and technical support provided by the software consultancy company and existence of procedures with well-defined tasks and responsibilities seem to have intermediate importance, representing, respectively, 31,96%, 27,84% and 27,84%. The factors focus on project benefits, buy-in from top management and change management and appropriate new procedures were the least selected by respondents with 19,59%, 16,49% and 13,40%.

It should also be noted that 5 respondents indicated factors other than those that appeared as a suggestion in the questionnaire, with the following aspects being designated: maintenance planning; web based; does not induce the benefits of unplanned outages x maintenance costs; support / manpower for implementation and recording of all data; and operational strategy in which it is included.

4.5. Decision-making of maintenance management software projects

The Table 11 (see Annex III – Table 11) show companies' responses to the question of how long they took to decide the purchase of the maintenance management software.

The option Do Not Know / Do Not Answer was the most indicated, represented by 24,7% of respondents. Respondents who selected this option were probably not involved in the software purchase process, did not remember the time the purchase process took, or simply chose not to answer the question.

As seen in the table above, the option regarding the longest duration of time, More than 1 year, was indicated by 23,7% of respondents, followed by the options 2 months to 6 months, Less than 2 months and 7 months to 12 months accounting for 22,7%, 16,5% and 12,4% respectively.

The results demonstrate that there is no option that is sufficiently expressive and that allows to identify a pattern regarding the duration time of the software purchase process.

To assess the opinion of respondents on some aspects that are considered important in choosing a maintenance management software a question was posed with eight different variables to be answered according to a Likert scale. The results are shown in Figure 15.

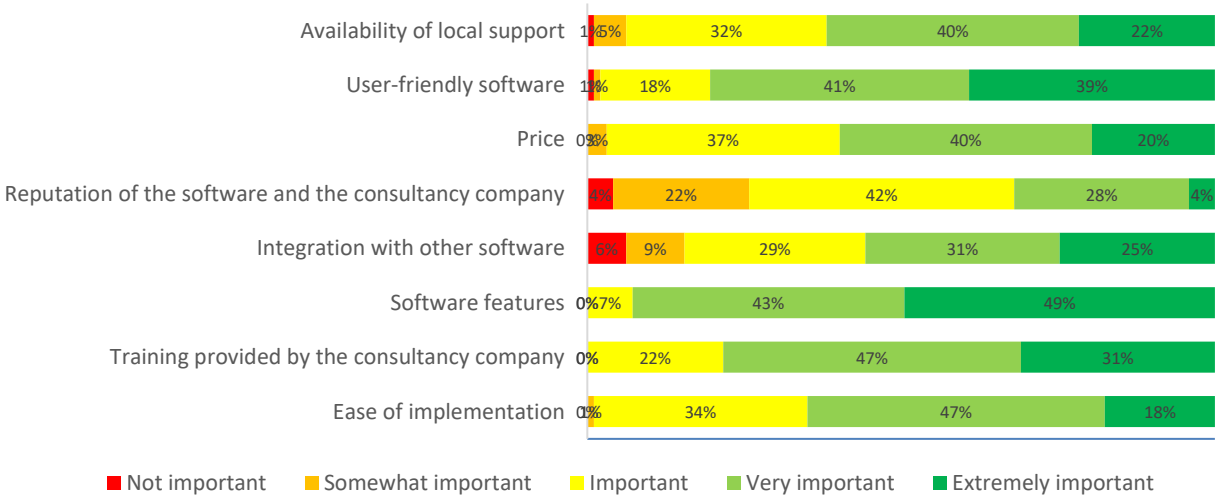


Figure 15 Important aspects in choosing maintenance management software

The most expressive variable is “software features” with 93% of respondents considering it as an aspect Very important or Extremely important. In contrast, the aspect that respondents most point out (25 people) as Not important or Somewhat Important is the “Reputation of the software and the consultancy company”, which also presents the lowest weighted average (3,06) among all aspects.

The aspects “Training provided by the consultancy company”, “Software features” and “User-friendly software” are the three most valued by the respondents with a weighted average of, respectively, 4,42, 4,09 and 4,16.

These results might be aligned to some extent with the study of Plant Maintenance (2004) which revealed that the ease of use and the general functionality and features of the

software are among the three factors considered most important by the study participants. The study of Plant Maintenance (2004) attributes the integration with other commercial software as the most important factor in the choice of a maintenance management software while the results of the questionnaire developed in this dissertation indicate the integration with other software as the 7th most important factor, with a weighted average of 3,59.

5. Conclusions and Recommendations

In this section, which represents the culmination of the entire research process carried out for the development of this dissertation, a brief synthesis of the main results of the research is made, with the purpose of extracting implications of the study. Some limitations of this study are discussed and recommendations for further research are also made in this section.

5.1. Conclusions

From the literature and the empirical research carried out, this work allowed the evaluation of the benefits of maintenance management software. The findings of this study suggest that maintenance management software is a useful tool for maintenance and brings several benefits to organisations. Most companies confirm the benefits obtained in the questionnaire, corroborating with different studies identified in literature review (e.g. Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001; Wireman, 2005).

Regarding the level of measurement of benefits, this research has shown that among all the benefits listed in the questionnaire, improved cost control, improved inventory control and reduced inventory costs, and reduced energy consumption are the benefits with greater emphasis on the attribution of financial value, and therefore, can be considered as the benefits with most explicit measurement. Based on the results obtained in the questionnaire, it becomes clear that the assessment of benefits at the financial level has room for improvement. This finding is consistent with Kans' (2012) research which found that although maintenance managers are aware of the benefits of IT investments in maintenance, they find it difficult to assess the benefits in financial value.

This study allowed to understand that there are 25,8% companies that do not use indicators. Therefore, it is recommended that these organisations implement metrics, considering that, as suggested by several authors such as Wireman (2005) or Simões et al. (2011), the establishment of metrics in maintenance would guarantee more control and better management of maintenance.

This research has found that there is a very positive perception of organisations regarding the success of the project of maintenance management software. Only 12,4% of the

companies participating in the questionnaire affirm that the project is seen as unsuccessful and 2,1% consider that evaluating the success of the project is not relevant. These values should be considered quite positive considering the several references in literature that warn of the possibility of failure to implement maintenance management software (Bagadia, 2006; Cabral, 2013; Cato and Mobley, 2001; Wireman, 2005).

The investigation of critical factors for success of the maintenance management software has shown that people's discipline in complying with procedures while using the software is key to the success of the project, as well as the features of the software itself, namely being user-friendly and appropriate for the organisation.

The research also identifies that features related to preventive maintenance, history of equipment failure, maintenance requests and indicators are used by most companies. There seems to be a relationship between the large number of companies obtaining benefits and the high rate of use of these features, which are indispensable for realising the benefits.

Regarding aspects that are important while choosing maintenance management software, software features, training provided by consultancy company and the ease of use of software were considered the most valued by respondents. This result seems to be in line with the study carried out by Plant Maintenance (2004).

Finally, it is also important to highlight the contribution of this study to the maintenance area and to the business world in general, as it provides real market data on the impact of maintenance management software.

5.2. Research Limitations

One of the limitations of this study is that it was based on the opinion of only one respondent per organisation, which means that the representation of the organisation could have been distorted by the opinion of only one individual. In addition, the fact that convenience sampling was used could mean that the results are not representative of the population.

Although the study allows conclusions to be drawn about the benefits that are obtained through the support of maintenance management software and the metrics that companies

establish and use, the current research was not specifically designed to analyse in detail the methodologies used to measure benefits.

Another important point to mention as a limitation of the study are the response options provided in the question related to business sector. Although the suggested business sectors may be too broad, other sectors may have been suggested and others possibly excluded, it is challenging to find a balance between a reasonable number of suggested sectors and the wide diversity of existing sectors.

5.3. Future Research

It is recommended that in the future more case studies be carried out in organisations, based on the benefits identified in this dissertation, in order to perceive, in a more detailed way, how the benefits are obtained and how they are measured. In agreement with Simões et al. (2011) which refer to the need to solidify the theory and promote more empirical approaches to maintenance performance, this future research studies would concentrate on understanding the methodologies that are being used to measure benefits, since the empirical results would be important to help organisations not only demonstrate a good use of the system and present results, but also to provide arguments to justify the purchase of a software.

There appears to be a shift away from viewing maintenance in a corrective perspective, since the results of this study indicate that 42,3% of organisations use maintenance management software to support predictive maintenance analysis. Although this figure can be considered quite satisfactory for Portuguese organisations, compared to the 11% of companies from the Netherlands, Germany and Belgium which are referred in the PwC and Mainnovation (2017) study as being at a level of predictive maintenance, it is strange that the reality between Portuguese and European companies is so different. It would be interesting to explore in detail the use of predictive maintenance, as well as further investigation regarding the concept of IoT and its applicability to maintenance management software is strongly recommended. Considerable more work needs to be carried out to determine how IoT could improve maintenance management and it would be also interesting to predict the evolution over time by both vendors of maintenance management software and vendors of equipment, considering that large amount of data from assets may be centralised in a maintenance management system.

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Annexes

Annex I - Questionnaire (Original - Portuguese version)

Annex II - Questionnaire (English versions)

Annex III - Frequency Tables

Annex I - Questionnaire (Original – Portuguese version)

Questionário

Benefícios da Utilização de Software de Gestão de Manutenção

O presente questionário surge no âmbito de um projeto de dissertação de Mestrado em Gestão Internacional, no Instituto Universitário de Lisboa (ISCTE-IUL). Este estudo conta com o apoio da APMI (Associação Portuguesa de Manutenção Industrial), da Navaltik Management (detentora do software de gestão de manutenção ManWinWin) e do Eng.º José Paulo Saraiva Cabral.

O questionário destina-se ao responsável pelo projeto de software de gestão de manutenção na sua empresa. A resposta é anónima e está garantido o tratamento confidencial da informação recolhida. Agradeço desde já a sua disponibilidade para colaborar neste estudo.

Para qualquer informação adicional poderá entrar em contato com o autor do estudo: João Folgosa (jdmcm@iscte.pt)

1. Utilização de software de gestão de manutenção

A sua empresa dispõe de um software de gestão de manutenção?

- Sim
- Não

2. Identificação do software de gestão de manutenção

Qual o software de gestão de manutenção utilizado na sua empresa?

(Opcional)

_____

3. Anos de utilização do software de gestão de manutenção

Há quantos anos é utilizado um software de gestão de manutenção na sua empresa?

- Menos de 2 anos
- 2 anos a 5 anos
- 6 anos a 10 anos
- Mais de 11 anos

4. Funcionalidades do software de gestão de manutenção

Indique as funcionalidades do software de gestão de manutenção utilizadas na sua empresa:

- Análise de manutenção preditiva
- Diagnóstico de avarias dos equipamentos
- Gestão de encomendas
- Gestão de pedidos de manutenção
- Gestão de stock de materiais
- Gestão orçamental
- Histórico de avarias dos equipamentos
- Indicadores
- Inventário de equipamentos
- Listagem de materiais por equipamento
- Planeamento de mão-de-obra
- Planeamento e agendamento de manutenção preventiva
- Planeamento e agendamento de ordens de trabalho

5. Fatores críticos para o sucesso de um software de gestão de manutenção

Assinale os fatores que considera mais importantes para o sucesso do software de gestão de manutenção nas organizações (assinale os 3 fatores mais importantes):

- Cumprimento disciplinado e continuado dos procedimentos
- Exigência da gestão de topo
- Existência de manual de procedimentos com tarefas e responsabilidades bem definidas
- Experiência e suporte técnico prestado pela empresa consultora de software
- Foco nos benefícios do projeto
- Formação adequada
- Gestão da mudança e novos procedimentos adequados
- Software apropriado
- Software user-friendly
- Outra: _____

6. Sucesso do software de gestão de manutenção na empresa

O projeto de software de gestão de manutenção na sua empresa é visto como bem sucedido?

- Sim
- Não
- Não relevante
- NS/NR

7. Critérios para aferição do sucesso do software de gestão de manutenção na empresa

Quais os critérios utilizados para aferir o sucesso do software de gestão de manutenção na sua empresa?
(Opcional) Por favor indique os critérios mais importantes – até 4 critérios

_____

8. Problemas na gestão de manutenção

O quadro apresentado de seguida contém um conjunto de problemas que podem existir na gestão de manutenção. Deverá assinalar (com um ✓) os problemas identificados antes da implementação do software de gestão de manutenção e os problemas identificados depois da implementação do software de gestão de manutenção, de acordo com a realidade na sua empresa.

	Antes da implementação do software de gestão manutenção	**Depois da implementação do software de gestão de manutenção**
Excesso de manutenção corretiva		
Falta de controlo de custos e pouco rigor na gestão orçamental		
Falta de controlo sobre colaboradores		
Falta de informação na tomada de decisões		
Falta de manutenção preventiva		
Falta de mão-de-obra		
Falta de materiais e/ou excesso de materiais		
Planeamento de trabalhos ineficiente		
Pouca disponibilidade dos equipamentos		
Pouca produtividade		
Problemas de segurança e inconformidades em auditorias		

9. Benefícios atingidos com o apoio de um software de gestão de manutenção

O quadro apresentado de seguida contém um conjunto de benefícios que podem ser obtidos com o apoio de um software de gestão de manutenção. Deverá assinalar o nível de cada benefício, de acordo com a realidade da sua empresa.

	NS/NR	**Não obtenho este benefício**	**Percecio no este benefício**	**Consigo medir este benefício**	**Meço efetivamente este benefício**	**Avalio este benefício em valor (€)**
Aumento de disponibilidade dos equipamentos						
Aumento de produtividade dos colaboradores						
Aumento do tempo de vida dos equipamentos						
Garantia de conformidade com a legislação em vigor						
Melhoria de imagem da área de manutenção e/ou da empresa						
Melhoria no controlo de custos						
Melhoria no controlo de inventário e redução de custos de inventário						
Redução de consumo energético						

10. Métricas/indicadores utilizados com recurso a um software de gestão de manutenção

Assinale as métricas/indicadores utilizados na sua empresa com recurso a um software de gestão de manutenção:

- Custo de manutenção corretiva vs custo total de manutenção
- Custo de manutenção preventiva vs custo total de manutenção
- Custo de manutenção vs faturação da empresa
- Custo de manutenção vs unidade produzida
- Disponibilidade / Indisponibilidade
- LCC (Life Cycle Costing)
- MTBF (Mean Time Between Failures)
- MTTR (Mean Time To Repair)
- MWT (Mean Waiting Time)

- OEE (Overall Equipment Effectiveness)
- Taxa de avarias
- Taxa de realização de ordens de trabalho
- Outra: _____

11. Tempo de tomada de decisão de compra do software de gestão de manutenção

Quanto tempo demorou a tomada de decisão de compra do software de gestão de manutenção na sua empresa?

- Menos de 2 meses
- 2 meses a 6 meses
- 7 meses a 12 meses
- Mais de 1 ano
- NS/NR

12. Aspetos importantes na escolha de um software de gestão de manutenção

Qual a importância de cada um dos seguintes aspetos na decisão de compra de um software de gestão de manutenção?

	Nada importante	**Pouco importante**	**Importante**	**Muito importante**	**Extremamente importante**
Facilidade de implementação					
Formação prestada pela empresa consultora					
Funcionalidades do software					
Integração com outros softwares					

Notoriedade do software e da empresa consultora					
Preço					
Software user-friendly					
Suporte local disponível					

13. Setor de negócio

Por favor indique o setor de atividade da sua empresa:

- Biotecnologia
- Construção
- Consultoria / Serviços
- Edifícios
- Educação
- Energia
- Hotelaria
- Indústria mineira
- Indústria transformadora
- Retalho
- Saúde
- Transportes
- Utilities / Comunicação
- Outra: _____

14. Dimensão da área de manutenção

Por favor indique o número de pessoas que colaboram na área de manutenção da sua empresa:

- 1 a 3 colaboradores
- 4 a 10 colaboradores
- 11 a 25 colaboradores
- Mais de 26 colaboradores

15. Função na empresa

Por favor indique a área funcional a que pertence:

- Diretor Geral
- Financeira
- Logística
- Manutenção
- Produção
- Qualidade
- TI
- Outra: _____

16. Anos de experiência profissional

Por favor indique os seus anos de experiência profissional:

- Menos de 2 anos
- 2 anos a 5 anos
- 6 anos a 10 anos
- Mais de 11 anos

Fim do Questionário

Obrigado pela sua colaboração.

A sua resposta ao questionário foi submetida com sucesso. Obrigado pela sua colaboração neste estudo.

Caso pretenda receber no futuro uma cópia gratuita deste estudo, deverá entrar em contato com o autor do estudo: João Folgosa (jdmcm@iscte.pt)

Annex II - Questionnaire (English version)

Questionnaire

Benefits of Maintenance Management Software

This questionnaire is part of a Master's thesis project in International Management at the University Institute of Lisbon (ISCTE-IUL). This study has the support of APMI (Portuguese Association of Industrial Maintenance), Navaltik Management (holder of the maintenance management software ManWinWin) and Eng. José Paulo Saraiva Cabral.

The questionnaire is addressed to the person responsible for the maintenance management software project in your company. The answers are anonymous and confidential treatment of the collected information is guaranteed. Thank you in advance for your willingness to cooperate in this study.

For any additional information you may contact the study author: João Folgosa (jdmcm@iscte.pt)

1. Use of maintenance management software

Does your company have a maintenance management software?

- Yes
- No

2. Identification of maintenance management software

What maintenance management software is used in your company? (Optional)

_____

3. Years of use of maintenance management software

How many years has maintenance management software been used in your company?

- Less than 2 years
- 2 years to 5 years
- 6 years to 10 years
- More than 11 years

4. Maintenance management software features

Please indicate the features of the maintenance management software used in your company:

- Predictive maintenance analysis
- Diagnosis of equipment failures
- Purchasing management
- Maintenance requests management
- Material stock management
- Maintenance budgeting control
- Equipment failure history
- Indicators
- Equipment inventory
- Material listing by equipment
- Man-hour planning
- Planning and scheduling of preventive maintenance
- Planning and scheduling of work orders

5. Critical factors for the success of maintenance management software

Please indicate the factors you consider most important to the success of maintenance management software in organisations (please tick the 3 most important factors):

- Disciplined and continuous compliance with procedures
- Buy-in from top management
- Existence of a manual of procedures with well-defined tasks and responsibilities

- Experience and technical support provided by the software consultancy company
- Focus on project benefits
- Adequate training
- Change management and appropriate new procedures
- Appropriate software
- User-friendly software
- Other: _____

6. Success of the maintenance management software in the company

Is the project of maintenance management software in your company seen as successful?

- Yes
- No
- Not relevant
- Don't know / No answer

7. Criteria for measuring the success of maintenance management software in the company

What criteria do you use to measure the success of maintenance management software in your company?
(Optional) Please indicate the most important criteria – up to 4 criteria

_____

8. Problems in maintenance management

The table below contains a set of problems that may exist in maintenance management. Please indicate (with ✓) the problems identified prior to the implementation of the maintenance management software and the problems identified after the implementation of the maintenance management software, according to the reality of your company.

	Prior to the implementation of maintenance management software	After the implementation of maintenance management software
Excess of corrective maintenance		
Lack of cost control and little accuracy in budget management		
Lack of control over employees		
Lack of information in decision making		
Lack of preventive maintenance		
Lack of manpower		
Lack of materials and/or excess materials		
Inefficient work planning		
Lack of equipment availability		
Low productivity		
Safety issues and nonconformities in audits		

9. Benefits achieved with the support of a maintenance management software

The table below contains a set of benefits that can be obtained with the supported of a maintenance management software. You should indicate the level for each benefit, according to the reality of your company.

	Don't know / No answer	Benefit is not obtained	Benefit is perceived	Benefit can be measured	Benefit is effectively measured	Benefit is evaluated in value (€)
Increased equipment availability						
Increased labour productivity						
Lengthened equipment lifetime						
Ensured compliance with the legislation in force						
Improved image of the maintenance area and/or the company						

Improved cost control						
Improved inventory control and reduced inventory costs						
Reduced energy consumption						

10. Metrics/indicators used and obtained with the support of maintenance management software

Please indicate the metrics/indicators used in your organisation that are obtained with the support of the maintenance management software:

- Cost of corrective maintenance vs total cost of maintenance
- Cost of preventive maintenance vs total cost of maintenance
- Cost of maintenance vs company revenue
- Cost of maintenance vs Unit produced
- Availability / Unavailability
- LCC (Life Cycle Cost)
- MTBF (Mean Time Between Failures)
- MTTR (Mean Time To Repair)
- MWT (Mean Waiting Time)
- OEE (Overall Equipment Effectiveness)
- Failure rate
- Rate of completed work orders
- Other: _____

11. Time to take the decision of purchasing a maintenance management software

How long did it take to decide to purchase maintenance management software in your company?

- Less than 2 months
- 2 months to 6 months
- 7 months to 12 months
- More than 1 year
- Don’t know / No answer

12. Important aspects in choosing maintenance management software

How important is each of the following aspects while taking the decision of purchasing a maintenance management software?

	Not important	**Somewhat important**	**Important**	**Very important**	**Extremely important**
Ease of implementation					
Training provided by the consultancy company					
Software features					
Integration with other software					
Reputation of the software and the consultancy company					
Price					
User-friendly software					
Availability of local support					

13. Business sector

Please indicate the business sector of your company:

- Biotechnology
- Construction
- Consulting / Services
- Facilities
- Education
- Energy
- Hospitality
- Mining
- Manufacturing
- Retail

- Healthcare
- Transportation
- Utilities / Communications
- Other: _____

14. Size of the maintenance area

Please indicate the number of people working in the maintenance area in your company:

- 1 to 3 employees
- 4 to 10 employees
- 11 to 25 employees
- More than 26 employees

15. Position in the company

Please indicate your functional area:

- Managing Director
- Finance
- Logistics
- Maintenance
- Production
- Quality
- IT
- Other: _____

17. Years of professional experience

Please indicate your years of professional experience:

- Less than 2 years
- 2 years to 5 years
- 6 years to 10 years
- More than 11 years

End of Questionnaire

Thanks for your collaboration.

Your response was successfully submitted. Thank you for your collaboration in this study.

If you wish to receive a free copy of this study in the future, please contact the study author: João Folgosa (jdmcm@iscte.pt)

Annex III - Frequency tables

		Frequency	Percent	Cumulative Percent
Valid	Biotechnology	0	0	0
	Construction	3	4,29	4,3
	Consulting / Services	2	2,86	7,2
	Facilities	6	8,57	15,8
	Education	1	1,43	17,2
	Energy	5	7,14	24,3
	Hospitality	4	5,71	30,0
	Mining	0	0	30,0
	Manufacturing	31	44,29	74,3
	Retail	3	4,29	78,6
	Healthcare	5	7,14	85,7
	Transportation	8	11,43	97,1
	Utilities / Communications	2	2,86	100,0
	Total	70	100,0	

Table 1 Distribution of companies per business sector

		Frequency	Percent	Cumulative Percent
Valid	1 to 3 employees	5	5,2	5,2
	11 to 25 employees	25	25,8	30,9
	4 to 10 employees	28	28,9	59,8
	More than 26 employees	39	40,2	100,0
	Total	97	100,0	

Table 2 Distribution of companies per size of the maintenance area

		Frequency	Percent	Cumulative Percent
Valid	Finance	0	0	0
	Managing Director	4	4,6	4,6
	IT	3	3,4	8,0
	Logistics	0	0	0
	Maintenance	77	88,5	96,6
	Production	2	2,3	98,9
	Quality	1	1,1	100,0
	Total	87	100,0	

Table 3 Distribution of respondents per position in the company

		Frequency	Percent	Cumulative Percent
Valid	Less than 2 years	0	0	0
	2 years to 5 years	11	11,3	11,3
	6 years to 10 years	12	12,4	23,7
	More than 11 years	74	76,3	100,0
	Total	97	100,0	

Table 4 Distribution of respondents per years of professional experience

		Frequency	Percent	Cumulative Percent
Valid	Product H	1	1,3	1,3
	Product I	1	1,3	2,6
	Product J	1	1,3	3,9
	Product K	1	1,3	5,3
	Product C	3	3,9	9,2
	Product L	1	1,3	10,5
	Product D	2	2,6	13,2
	Product E	2	2,6	15,8
	Product M	1	1,3	17,1
	Product N	1	1,3	18,4
	Product A	48	63,2	81,6
	Product F	2	2,6	84,2
	Product O	1	1,3	85,5
	Product P	1	1,3	86,8
	Product B	7	9,2	96,1
	Product Q	1	1,3	97,4
	Product G	2	2,6	100,0
	Total	76	100,0	

Table 5 Maintenance management software used by companies

		Frequency	Percent	Cumulative Percent
Valid	Less than 2 years	12	12,4	12,4
	2 years to 5 years	22	22,7	35,1
	6 years to 10 years	33	34,0	69,1
	More than 11 years	30	30,9	100,0
	Total	97	100,0	

Table 6 Distribution of companies per years of use of maintenance management software

		Responses N	Percent of Cases
Features used[a]	Predictive maintenance analysis	41	42,3%
	Diagnosis of equipment failures	35	36,1%
	Purchasing management	42	43,3%
	Maintenance requests management	81	83,5%
	Material stock management	62	63,9%
	Maintenance budgeting control	28	28,9%
	Equipment failure history	83	85,6%
	Indicators	72	74,2%
	Equipment inventory	73	75,3%
	Material listing by equipment	55	56,7%
	Man-hour planning	52	53,6%
	Planning and scheduling of preventive maintenance	90	92,8%
	Planning and scheduling of work orders	90	92,8%

a. Dichotomy group tabulated at value 1.

Table 7 Features of maintenance management software used by companies

Responses

		N	Percent of Cases
Maintenance indicators used[a]	Cost of corrective maintenance vs total cost of maintenance	64	66,0%
	Cost of preventive maintenance vs total cost of maintenance	65	67,0%
	Cost of maintenance vs company revenue	30	30,9%
	Cost of maintenance vs Unit produced	21	21,6%
	Availability / Unavailability	46	47,4%
	LCC (Life Cycle Costing)	11	11,3%
	MTBF (Mean Time Between Failures)	55	56,7%
	MTTR (Mean Time To Repair)	53	54,6%
	MWT (Mean Waiting Time)	25	25,8%
	OEE (Overall Equipment Effectiveness)	20	20,6%
	Failure rate	62	63,9%
	Rate of completed work orders	59	60,8%

a. Dichotomy group tabulated at value 1.

Table 8 Indicators used in the organisation and obtained with the support of the maintenance management software

		Frequency	Percent	Cumulative Percent
Valid	Yes	79	81,4	81,4
	No	12	12,4	93,8
	Not relevant	2	2,1	95,9
	DK/NA	4	4,1	100,0
	Total	97	100,0	

Table 9 Success of the maintenance management software within companies

		Responses N	Percent of cases
$factors[a]	Disciplined and continuous compliance with procedures	62	63,9%
	Buy-in from top management	16	16,5%
	Existence of a manual of procedures with well defined tasks and responsibilities	27	27,8%
	Experience and technical support provided by the software consultancy company	27	27,8%
	Focus on project benefits	19	19,6%
	Adequate training	31	32,0%
	Change management and appropriate new procedures	13	13,4%
	Appropriate software	42	43,3%
	User-friendly software	49	50,5%

a. Dichotomy group tabulated at value 1.

Table 10 Critical factors for the success of maintenance management software

		Frequency	Percent	Cumulative Percent
Valid	Less than 2 months	16	16,5	16,5
	2 months to 6 months	22	22,7	39,2
	7 months to 12 months	12	12,4	51,5
	More than 1 year	23	23,7	75,3
	DK/NA	24	24,7	100,0
	Total	97	100,0	

Table 11 Time to take the decision of purchasing a maintenance management software