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Impact of ISO 9001 and TPM Integration

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ABSTRACT

During the recent years, Integrated Management System (IMS) has gained notable importance by researchers and practitioners due to the benefits of this practice. Thus, the aim of this research is to present and implement a model to integrate Total Productive Maintenance (TPM) and three different function-specific management system standards, namely ISO 9001:2015, ISO 45001:2018 and ISO 14001:2015. The methodology used is a content analysis based on a literature review that allowed identifying the common elements to propose the TPM ISO model and a case of study is developed to validate the proposal. Findings show a set of four phases as a framework to help organizations to deal with integration challenges. The originality of this investigation is threefold: the proposed TPM ISO model, the introduction of environmental management in TPM and its practical application with the case study.

Keywords: Total Productive Maintenance, ISO 9001, Integrated Management Systems, Management Systems.

1. INTRODUCTION

In today's competitive business scenario, manufacturing industries are constantly looking for ways to improve the efficiency of production (Sahoo, 2018). The survival and competitiveness of manufacturing firms depend on the practices and adaptive capacities in external environments, which are attributed to shifts in customer preferences, government regulations, technology and competitors (Satolo et al. 2017). Liability in connection with quality, environment, occupational health and safety as well as social accountability, is important for the competitiveness and positive image of organizations (Jørgensen et al. 2006). Kumar and Maiti (2017) recognize that the implementation of management systems standards (MSSs) contributes to the development of a standardized system of governance through standard operating procedures, internal audits and management reviews to achieve the needs and expectations of all the interested parties in a proactive manner. In this way, the implementation of certified and non-certified MSSs is an indicator of responsibility and concern for stakeholder relations from the organization (Jørgensen et al. 2006).

The implementation of standards has been an important activity for organizations irrespective of their size, sector or nature of the business and has become a widespread phenomenon around the world (Zutshi and Sohal, 2004). The most prominent normalization body to do so is the International Organization for Standardization (ISO). Some of these MSs have gained global recognition such as ISO 9001 as a quality management system (QMS) and ISO 14001 as an

environmental management system (EMS) (Karapetrovic et al. 2010). In 2018, the ISO 45001 was introduced, and it specifies requirements for an occupational health and safety (OH&S) management system. This will replace the Occupational Health and Safety Assessment Series OHSAS 18001, issued by the British Standards Institution that will stay valid until the year 2021 (Gasiorowski-Denis, 2018a).

However, companies have difficulties dealing with separate MSSs covering quality, safety, environment, financial and other issues, and ensuring that they align with the organizations' strategy (Garengo and Biazzo, 2013). Due to the proliferation of function-specific management systems and related standards, a need has emerged to somehow integrate them into a single MS in order to reduce wasteful redundancies and possibly generate synergy effects (Karapetrovic, 2002).

Integrated Management System (IMS) is defined by ISO, (2018) as "*the outcome of the process of integrating requirements from multiple management system standards into a singular management system within an organization".* When the companies' strategy is to implement more than one management system, there is a clear advantage of doing it supported on an integrated approach with a careful pre-planned design in order to maximize the benefits (see e.g., Karapetrovic et al. 2010; Bernardo et al. 2015; Zeng et al. 2011), and minimize difficulties (see e.g., Bernardo et al. 2012; Simon and Douglas, 2013; Sampaio et al. 2012). In the last years, ISO have made notable efforts in the revisions of its standards to make them more compatible in content and terminology, so it is possible to effectively combine and integrate them. New and updated ISO standards adopt Annex SL, thus sharing a high-level structure (HLS), which consist on an identical core text and terms and definitions share with each other (ISO, 2017). This means that they share the same structure by clauses and terms used but the content differs depending on the specific function of each the standard.

On the other hand, manufacturing companies aim to optimize the availability and reliability of production equipment, and maintain its operability at an acceptable cost level (Ahmed et al. 2005). Total Productive Maintenance (TPM) initiatives in production help in streamlining the manufacturing and other business functions, and garnering sustained profits (Ahuja and Khamba, 2008a). While the world has been adopting quality as a competitive strategy through ISO 9001, a major portion of organizational arena has started to adopt maintenance as strategy through the implementation of TPM (Sivaram et al. 2012). Nevertheless, it alone cannot solve all the current needs of manufacturing organizations but has the potential to transcend into other major dimensions (Ahmed et al. 2005).

Both TPM and ISO 9001 are regarded as competitive strategies and it is worthwhile to explore the connectivity prevailing between them. Sivaram et al. (2012) indicated the substantial benefits of implementing TPM and ISO 9001-based Quality Management System by making a literature review and later proposing the TPM 9001:2008 model (Sivaram et al. 2014) which infused TPM requirements into ISO 9001:2008. With this, an open discussion can be assumed and the question to be answered is if other ISO standards could also be integrated with TPM as well.

Thus, from the above mentioned, the aim of this research is to analyze and update the TPM 9001:2008 model proposed by Sivaram et al. (2014) according to the ISO 9001:2015 version that shares the HLS with ISO 45001:2018 and ISO 14001:2015. This is to propose the construction of a new updated model which allows the integration of these standards with TPM finding their compatible and complementary possibilities. Then, a case study is presented where the TPM and ISO 9001 interactions are analyzed to conceptualize the integration process using the TPM ISO proposed model.

After this introduction, the paper continues with a brief literature review of TPM focusing in the quality and OH&S factors. Then a review of the ISO 9001:2015, ISO 45001:2018 and ISO 14001: 2015 is done in order to present the connections between them and TPM, becoming the base of the methodology applied. After this, the basis of the updated TPM ISO model and the case study are presented. And finally, conclusions are formulated to describe the contributions, implications and limitations of this investigation.

2. LITERATURE REVIEW

In the last decade, the number of management systems (MSs) have increased tremendously due to the common purpose of facilitating organizations to systematically address various stakeholders' requirements (Asif and Joost de Bruijn, 2010). In this section, a brief description of the ISO MS standards involved in this investigation, their integration and TPM will be done in order to show their integration possibilities.

2.1 Total Productive Maintenance (TPM)

Seiichi Nakajima popularized the TPM concept through the Japanese Institute of Plant Engineers (now known as Japanese Institute of Maintenance, JIPM) in 1971, by proposing the involvement of the organization's entire human force towards carrying out the maintenance activities to enhance the availability, performance, quality, reliability and safety of equipment (Sivaram et al. 2012). TPM, with total employee involvement, emerged over the years as a successful and sustainable maintenance strategy for organizations of all types based on the team working philosophy (Ahmed et al. 2005). This drove companies to change roles of operators to allow them to carry out routine maintenance and assuming more responsibility of the process.

TPM is a manufacturing program designed primarily to maximize equipment effectiveness throughout its entire life through the participation of the entire work force (Nakajima, 1988). Though originated in Japan, TPM is widely accepted and successfully implemented throughout the world and western organizations started to show interest in TPM as a complement of the Total Quality Management (TQM) strategy (Ireland and Dale, 2001). Despite TPM is a productive maintenance strategy for manufacturing organizations and its mission is directed toward elimination of equipment and plant maintenance, it can cope with the dynamic needs inside the company by discovering the hidden or underutilized resources (Ahmed et al. 2005).

Park and Han, (2001) described TPM as a synergistic relationship among all organizational functions, but particularly between production and maintenance, for continuous improvement of product quality, operational efficiency, capacity assurance, and safety.

Sivaram et al. (2012) identified a large number of studies that has been conducted in the TPM implementation area. From describing the origin (see e.g., Ahuja and Khamba, 2008; Mad and Ramayah, 2010; Rodrigues and Hatakeyama, 2006), growth (see e.g., Cua et al. 2001; Kodali and Chandra, 2001; Thun, 2008) and importance (see e.g., Ahmed et al. 2005; Kumar and Maiti, 2017; Kodali and Chandra, 2001) of TPM around the world to the description of several case studies (Ireland and Dale, 2001; Sahoo, 2018; Chan et al. 2005) it was confirmed that TPM has been subjected to further expansion by both researchers and practitioners to act as a world class performance improvement strategy rather than just a maintenance strategy (Ahmed et al. 2005). The results of Sivaram et al. (2012) literature review revealed that TPM is surmounted by three sets of facets namely (1) pillars, (2) measures and (3) losses.

Thus, it is clear that TPM has the potential to transcend into other major dimensions inside organizations. One of the imperatives for that is to apply a total participatory equipment maintenance technique by knowledge-workers in teams (Ahmed et al. 2005). This demands to think not only in maintenance performance because TPM management brings everyone, from equipment designer to operators, together to work under autonomous and small groups environment by keeping the production plant and equipment at its highest productive level through the cooperation of all areas of an organization (Ahmed et al. 2005). Effective TPM initiatives can strategically contribute towards improving the competitive position of the organization leading to enhanced productivity, returns on net assets and returns on capital employed (Ahuja and Khamba, 2008b).

2.1.1 TPM Pillars

In table 1, the core TPM initiatives are classified into activities for accomplishing the manufacturing performance improvements and include: (1) Autonomous Maintenance; (2) Planned Maintenance; (3) Quality Maintenance; (4) Focused Improvement; (5) Development Management or Early Equipment Maintenance; (6) Education and Training; (7) Safety, Health and Environment; and (8) Office TPM.

An effective TPM program requires the implementation of the above mentioned eight pillars and it involves everyone in the organization, from top-level management to production mechanics, and from production support groups to suppliers. These objectives require strong management support as well as continuous use of work teams and small group activities to achieve incremental improvements (Ahuja and Khamba, 2008b).

TPM Pillar	*Description*
(1) Autonomous Maintenance	Fostering operators ownership of equipment making them responsible for carrying out basic maintenance
(2) Planned Maintenance	Planning efficient and effective maintenance scheduled using the historical failure rate and life cycle of equipment
(3) Quality Maintenance	Quality ingrained in the equipment to achieve defect reduction and consequent profit improvement. Tracking and addressing equipment problems and root causes.
(4) Focused Improvement	Use of cross-functional teams for improvement activities for systematic identification and elimination of process losses through structured Root Cause Analysis practices to achieve improved Overall Equipment Efficiency on production systems.
(5) Development Management	Create maintenance improvement initiatives using learning from existing systems to new systems. Design of new equipment using lesson learned from previous TPM activities.
(6) Education & Training	Imparts technological, quality control and interpersonal training to develop multi-skilling of employees and aligning them to organizational goals. Bridging of the skills and knowledge gap through education programs for all workers
(7) Safety, Health &Environment	Ensure safe working environment by providing a working environment free of accidents and injuries. Elaboration of standard operating procedures.
(8) Office TPM	Spread of the TPM principles to administrative functions within an organization to improve synergy between various business functions. This will focus on addressing cost-related issues. Apply 5S in office and working areas.

Table 1. TPM pillars description. Source: Ahuja and Khamba, (2008a).

TPM provides a comprehensive, life cycle approach, to equipment management that minimizes equipment failures, production defects, and accidents. To take better decisions to effectively and efficiently manage production systems, it is necessary for managers to establish appropriate metrics for measurement purposes (Binti et al. 2016). Therefore, the Overall Equipment Efficiency (OEE) is one of the most recognized measures of TPM to evaluate the effectiveness of the equipment based on the concept of losses reduction of the processes that highlights the hidden and unused capacity in an organization (Ahmad et al. 2018).

2.1.2 Overall Equipment Effectiveness

TPM employs OEE as a quantitative metric for measuring the performance of a productive system. OEE methodology incorporates metrics from all manufacturing equipment into a measurement system that helps manufacturing and operations teams to improve equipment performance and, therefore, reduce equipment cost of ownership (Ahuja and Khamba, 2008b).

$$OEE = Availability \times Performance\ efficiency \times Rate\ of\ quality$$

OEE is calculated by obtaining the product of availability of the equipment, performance efficiency of the process and rate of quality products. These calculations are explained in Table 2.

Availability	$\frac{Loading\ time - Downtime}{Loading\ time}\ x\ 100\%$
Performance efficiency	$\frac{Processed\ amount}{Operating\ Time\ /\ Theoretical\ cycle\ time}\ x\ 100\%$
Rate of quality	$\frac{Processed\ amount - Scrap}{Processed\ amount}\ x\ 100\%$

Table 2. OEE calculations Source: Chan et al. (2005), Ahuja and Khamba, (2008a)

OEE metric has become widely accepted as a quantitative tool essential for the measurement of productivity in manufacturing operations (Ahuja and Khamba, 2008a). The OEE measure is central to the formulation and execution of a TPM improvement strategy (Dal et al. 2000) and it offers a starting-point for developing quantitative variables for relating maintenance measurement to corporate strategy to meet the challenges put forward by globally competing economies (Binti et al. 2016). Enhancement of OEE leads to the reduction or elimination of the six major losses enumerated in the previous section (Sivaram et al., 2012).

2.1.3 Losses Reduction

A key objective of TPM is to eliminate or minimize all losses related to manufacturing system to improve overall production effectiveness (Sharma et al. 2006). It has been observed that other than equipment related losses, losses affecting human performance and energy/yield inefficiencies also need to be accounted appropriately for achieving world-class performance. The sixteen major losses impeding manufacturing performance are identified in Table 3. TPM practices that lead to improvement strategies are developed for reducing the losses impact on the manufacturing systems (Ahuja and Khamba, 2008c).

1 Breakdown/failure loss	Losses due to failure. Types of failure include sporadic function-stopping failures and function-reducing failures in which the function of the equipment drops below normal levels
2 Set-up and adjustment loss	Stoppage losses that accompany set-up changeovers. These losses are caused by changes in operating condition. Equipment changeovers require a period of shutdown so that the tools can be exchanged.
3 Reduced speed loss	Losses due to actual operating speed falling below the designed speed of the equipment
4 Idling and minor stoppage loss	Losses that occur when the equipment temporarily stops or idles due to sensor actuation or jamming of the work. The equipment will operate normally through simple measures (removal of work and resetting).
5 Defect and rework loss	Volume/time losses due to defect and rework (disposal defects), financial losses due to product downgrading, and time losses required to repair defective products to turn them into excellent products.
6 Start-up loss	When starting production, the losses that arise until equipment start-up, running-in and production-processing conditions stabilize.
7 Tool changeover loss	Stoppage losses caused by changing tools that demand the machine to stop due to breakage or caused by changing when the service life.
8 Planned shutdown loss	Losses that arise from planned equipment stoppages at the production planning level in order to perform periodic inspection and statutory inspection
9 Distribution / logistic loss	Losses occurring due to inability to automate, e.g. automated loading or unloading leading to manpower reduction not implemented
10 Line organization loss	These are waiting time losses involving multi-process and multi-stand operators and line-balance losses in conveyor work
11 Measurement and adjustment loss	Work losses from frequent measurement and adjustment in order to prevent the occurrence and outflow of quality defects or reworks
12 Management loss	Waiting losses that are caused by management, such as waiting for materials, waiting for tools, waiting for instructions, waiting for repair of breakdowns, etc.
13 Motion-related loss	Losses due to violation of motion economy, losses that occur as a result of skill differences and walking losses attributable to an inefficient layout
14 Yield loss	Material losses due to differences in the weight of the input materials and the weight of the quality products
15 Consumables loss	Financial losses (expenses incurred in production, regrinding, which occur with production or repairs of dies, jigs and tools due to aging beyond service life or breakage
16 Energy loss	Losses due to ineffective utilization of input energy (electricity, gas, fuel oil, etc.) in processing

Table 3. 16 Major Losses. Source: Ahuja and Khamba, (2008a), Sharma et al. (2006).

2.2 ISO Standards

International Organization for Standardization (ISO) has developed standards for some of the MSs, including quality, environment, health and safety, customer satisfaction, auditing, among others. Some of the ISO standards can be certified by an institution accredited for this purpose, named certification bodies that evaluates the documentation evidencing that the management system implemented within the organization is complying with the standard requirements.

New and updated ISO standards presented from 2015 adopt Annex SL, thus sharing a high-level structure (HLS), identical core text, terms and definitions with the general ISO harmonized requirement for all MSSs of the different specialized disciplines (Anttila and Jussila, 2017). This means that they share the same structure by clauses and terms used but the content differs depending on the emphasis or specific function of the standard. The three standards analyzed in this investigation are based on this structure. This framework appears to be designed to facilitate the integration of new management topics into an organization's established management systems as Jonker and Karapetrovic, (2004) stated, ISO was making an effort to harmonize the structure of the existing and emerging MSSs to reach a fully integrated international standard. Table 4 list the clauses based on the HLS.

Clause 1: *Scope*	Explains the scope of the standard, what it is for and what it encompasses. It introduces the requirements of the management system which together with the key intended outcomes include: enhancement of performance, conforming to compliance obligations and fulfilment of objectives.
Clause 2: *Normative references*	Contains the normative references associated with the scope of the management system that should be take into account.
Clause 3: *Terms and definitions*	Lists the terms and definitions that apply to the standard. The new and updated standards extend the list of terms and definitions from previous standards combining the mandated HLS terms and definitions together with the more specific terms and definitions associated with the management systems.
Clause 4: *Organizational context*	Sets out the requirements for an organization to take a high level overview of the business, considering the key internal and external factors which impact it, and how it should respond in the form of a defined management system.
Clause 5: *Leadership*	Introduces some significant changes on overall leadership and commitment and the expectations for top management to engage more fully with the critical aspects of the quality management system.
Clause 6: *Planning*	Introduces the concept of risk (and opportunity). The approach is based on the audit being built around areas of risk to the organizations' business, and auditing in depth to assess whether the organization is managing that risk effectively.
Clause 7: *Support*	Gathers together in one place all the areas relating to the "people, place and procedural" aspects of the management systems such as resources, competence, awareness, communication and documented information. As a function of planning, such resources should be determined and provided.
Clause 8: *Operation*	Represents the operational control and emergency planning parts of the current standard. The overall purpose of operational planning and control is to ensure that processes are in place to meet the management system requirements
Clause 9: *Performance Evaluation*	The range of monitoring and measurement required to evaluate the performance and the effectiveness of the management system. These need to be determined for those processes and activities which relate to the management system scope and to evaluate the meeting of compliance obligations through: monitoring, measurement, analysis and evaluation, internal audit and management review.
Clause 10: *Improvement*	This states that the organization shall determine opportunities for improvement and implement necessary actions to achieve intended outcomes.

Table 4. ISO HLS Clauses. Source: ISO (2015a, 2015b), ISO (2018b)

2.2.1 ISO 9001 for Quality Management

In an organization, quality is directly related to the identification and satisfaction of the needs and expectations of customers, other stakeholders and the community in which the company operates (Magd and Curry, 2003). Quality management combines management techniques and models that strive for excellence in projects, processes, products, and services through continuous improvement (De Oliveira, 2013)

In 1987, the ISO released the ISO 9000 series of quality standards which immediately received global recognition (Garengo and Biazzo, 2013). ISO 9001 is a standard that "sets out interrelated and interacting elements of an organization to establish policies and processes to achieve the objectives with regard to quality resulting in a quality management system based on a number of management principles including a strong customer focus, the motivation and implication of top management, the process approach and continual improvement" (ISO, 2015b). ISO 9001 describes a set of fundamental elements that enable the design and implementation of quality management systems (Zeng et al. 2007) and proposes guidelines to systematize and formalize a series of company processes into a series of procedures, and to document this implementation (McLean et al. 2017). Using ISO 9001 helps ensure that customers get consistent, good-quality products and services, which in turn brings many business benefits (Zaramdini, 2007). ISO 9001 has contributed in the development of a standardized system of governance through standard operating procedures, internal audits and management reviews to achieve customer's needs and expectations in a pro-active manner (Kumar and Maiti, 2017).

The 'ISO Survey 2018' results released annually by ISO on the certification of ISO 9001 and all certifiable ISO standards, reveals that the adoption of this standard in organizations is situated in the majority of the countries, with 878,000 valid certificates around the world (ISO, 2018c).

The last revision made for the ISO 9001 in 2015 adds focus on risk-based thinking to identify and analyze potential risks that could arise both from inside and outside of the organizations, the consideration of the organizational stakeholders' needs and the importance of knowledge management (Sari et al. 2017).

2.2.2 ISO 45001 for Occupational Health and Safety Management

Constant technological progress and intense competitiveness as a result of globalization implies change in working conditions inside organizations (De Oliveira, 2013). This change usually generates occupational risks that can be identified and controlled by implementing an OH&S management system (Fernández-Muñiz et al. 2012). An efficient OH&S MS is necessary to inform collaborators, motivate them to act in a prudent and healthy manner, and provide mechanisms that companies can implement to monitor improvement in working conditions (De Oliveira, 2013).

Before ISO created a standard for occupational health and safety (OH&S), the Occupational Health and Safety Assessment System OHSAS 18001 standard, from the British Standards Institution

(BSI), gained considerable worldwide acceptance and a large number of firms, of various sizes and from different sectors, have implemented it (Fernández-Muñiz et al. 2012). OHSAS 18001 allows organizations to consistently identify and control its health and safety risks, reduce the potential for accidents, aid legislative compliance and improve overall performance (Chang and Liang, 2009). Until the year 2018, OHSAS had been the most recognized standard for OH&S and the ISO 45001 builds on the success of this earlier international standard. ISO 45001 for OH&S first publication was in 2018 and despite of its predecessor OSHAS 18001, not much research in the frame of integration of this barely new management system has been done. ISO 45001 enables organizations to put in place an occupational health and safety management system to manage their OH&S risks and improve their OH&S performance by developing and implementing effective policies and objectives (Gasiorowski-Denis, 2018b). It aims to provide a safe and healthy workplace for employees and visitors. The main role of the ISO 45001 standard is to serve as a useful instrument to enable an organization to proactively improve its occupational health and safety performance, regardless the size, type and nature of the organization (Darabont et al. 2017). However, the following differences between these management systems have been highlighted (Gasiorowski-Denis, 2018b):

- ISO 45001 concentrates on the interaction between an organization and its business environment while OHSAS 18001 was focused on managing OH&S hazards and other internal issues.
- ISO 45001 is process-based while OHSAS 18001 is procedure-based
- ISO 45001 is dynamic in all clauses while OHSAS 18001 is not
- ISO 45001 considers both risk and opportunities while OHSAS 18001 deals exclusively with risk
- ISO 45001 includes the views of interested parties while OHSAS 18001 does not

2.2.3 ISO 14001 for Environmental Management

With the increasing concern about the impact of industrial process on the environment, a large number of policies, processes and auditing protocols appear on the business context to reduce material waste and pollutants emission. The ISO 14001 certification has reached high levels of popularity and the number of certified companies has grown very sharply since its appearance in 1996 (González-Benito and González-Benito, 2008). Jørgensen et al. (2006) defined an environmental management system as ‘‘a part of an organization’s management system used to develop and implement its environmental policy and to manage its environmental aspects’’. ISO 14001 establishes requirements to be complied in relation to activities which have an environmental impact with a model that provides a systematic framework to incorporate environmental concerns into a company’s operations (Heras-Saizarbitoria and Boiral, 2013). This International Standard helps an organization achieving the intended outcomes of its environmental management system, which provide value for the environment, the organization itself and interested parties ((ISO, 2015a). This allowed to set out the criteria for an EMS and can be certified

to empower companies with mechanisms that have the potential to reduce environmental damage, such as the benefits that offset the costs of their implementation (De Oliveira, 2013). ISO 14001 is based on the concept that better environmental performance can be achieved when environmental aspects are systematically identified and managed giving a major contribution to sustainability, through pollution prevention, improved environmental performance and complying with applicable laws (da Fonseca, 2015).

There are more than 300,000 certificates of ISO 14001 in 171 countries around the world (ISO, 2018c) becoming an international standard of worldwide acceptance, specifically, the second most implemented and certified after the ISO 9001. On the ISO 14001 Continual Improvement Survey 2013 Executive Summary the identified factors that influenced the adoption were: opportunities for integration with other management standards applied by the organization (such as ISO 9001, ISO 50001, ISO 26000, and OHSAS 18001), financial benefits, government requirements and public image (ISO, 2014).

2.3 Integration of Management Systems

In order to address the needs of different stakeholders, companies can implement a large number of function-specific MSs (Zeng et al. 2007). As presented previously, quality management system is implemented to meet customer specifications; an environmental management system is implemented to prove that the processes, products and operations do not affect the natural surroundings in a harmful way; an organizational health and safety management systems can show good corporate concern about the work conditions of the employees (Karapetrovic and Jonker, 2003). The list of MSs is as long as the number of stakeholders' expectations in the business that want to be satisfied. The efforts to fulfill the needs of the interested parties through the execution of business operations are often facilitated by management sub-systems that provide a systematic way to regulate the behavior of the system so that it consistently behaves in the desired manner (Karapetrovic et al. 2010).

It is due to the proliferation of function-specific MSSs and the related costs of implementation and assessment that business organizations have begun questioning the introduction of MSS as completely separate entities and to somehow integrate management systems in order to reduce wasteful redundancies, facilitate implementation and possibly generate synergetic effects (Jonker and Karapetrovic, 2004). When organizations have multiple MSs implemented, the next step is to consider managing them as a single system, the integrated management system (IMS), in order to benefit from the related synergies (Bernardo et al. 2015).

Based on the literature review made by Sampaio et al. (2012), the IMS can be described as the organizational structure, resources and procedures that supports the planning and monitoring all the MSs activities aligning them to the strategy of an organization. The similar structure, language and steps to follow of the Plan-Do-Check-Act (PDCA) cycle in the MSs can facilitate organizations to create an effective integration strategy. These similarities may lead to the

integration of the standards thereby achieving synergies and then increasing benefits. Therefore, organizations need a framework to integrate these management sub-systems and facilitate their contribution to the functioning of the overall business MS (Karapetrovic et al. 2010). This is consistent with Rocha et al. (2007)'s sustainable development definition, where the IMSs have to be able to make some changes to its structure, modify or create new MSs according to three different dimensions:

(1) *Ascension:* The organization may choose to enhance the level of satisfaction for a particular stakeholder. Under such a scenario, the internal MS dedicated to that stakeholder is 'ascended'.
(2) *Augmentation*: An organization may need to 'augment' an existing MS in order to develop a more in-depth understanding in some specific issues or part of the system.
(3) *Assimilation*: In the never-ending search for increasing productivity, the organization may 'assimilate' its internal MSS so that they work as one.

Integration as a strategic and inherent approach is a solution to problems related to achieving 'real' continuous improvement such as improved competitive advantages and contributing to sustainable development (Jørgensen et al. 2006). Bernardo et al. (2015) recognized the benefits of management system integration finding improvements in efficiency (cost and time), customer satisfaction, employees' motivation, systematization (documentation and work procedures), market share, external image, competitive advantages, relationship with suppliers, quality and performance. There have been several studies describing the integration process (see Table 5). For example, Bernardo et al. (2015) focused on the "how" and proposed that the integration process can be defined according to four main aspects: implementation strategy, integration methodology, integration level and audit systems' integration. Other researches focus on the "why" based on the benefits of integration such as costs savings, operational benefits, better external image and improved customer satisfaction (Zeng et al. 2011; Asif and Joost de Bruijn, 2010).

	QM (ISO 9001)		*EM (ISO 14001)*		*OH&S (OSHAS 18000 / ISO 45001)*		*INTEGRATION*	
Benefits	Improved customer satisfaction, systematization, profitability, sales and sales growth, awareness of procedural problems, better management control.	Bernardo et al. (2015), Casadesús and Karapetrovic (2005), Tarí et al. (2012)	Improved image, Environmental performance, profitability, improvement in customer satisfaction, improved relations with stakeholders	Curkovic and Sroufe (2011), Berthelot et al. (2003), Tarí et al. (2012)	More motivated staff, improved working conditions, accidents prevention	Santos et al. (2016), Abad et al. (2013)	Management cost reduction, Task simplification, Unification of internal audits, Elimination of conflicts between individual systems.	De Oliveira Matias and Coelho (2002), Zeng et al. (2011), Bernardo et al. (2015)
Motivations	External and internal reasons, market forces, mixed motives (developmental, non-developmental).	Sampaio et al. (2012), Zaramdini (2007), Sadikoglu and Zehir (2010)	Relationships with authorities and stakeholders, commitment to environmental protection, risk reduction of adverse environmental impact, customer requirements, public image.	Hazudin et al. (2015), Adams (1999), da Fonseca (2015)	Comply with legal obligations, corporate image, subsidies, prizes, tax benefits, provide a safety work environment.	Qi et al. (2013), Fernández-Muñiz et al. (2012)	Reduction of cost and duplication of policies, procedures and records, tasks duplication and documentation improvement.	Bernardo et al. (2012), Sampaio et al. (2012), Rocha et al. (2007)
Implementation	Implementation models, Promoting the process approach for the implementation,	Srivastav (2010), Heras-Saizarbitoria and Boiral (2013), Anttila and Jussila (2017)	Environmental laws analysis to define the level of compliance from country to country.	Curkovic and Sroufe (2011), da Fonseca (2015)	External audit by an independent body to perform a gap analysis between organizations' practices and OH&S requisites	Darabont et al. (2017), Borella and Rodrigues (2016)	Transition from separate to integrated management systems, levels of integration, models of integration.	Beckmerhagen et al. (2003), Jørgensen et al. (2006), Sampaio et al. (2012), Garengo and Biazzo (2013), Rocha et al. (2007)
Performance	Improved quality of products and/or services, increased productivity, improvements in customer feedback actions.	Terziovski et al. (2003), Kumar and Maiti (2017), Sampaio et al. (2012)	Certification measures EMS implementation intensity, variations in EMS implementation performance results, overall facility-level business performance.	Darnall et al. (2008), Borella and Rodrigues (2016)	Better safety culture and climate, improved product quality, increased productivity.	Abad et al. (2013) Darabont et al. (2017) Bottani et al. (2009), Ghahramani (2016)	Ensuring the compatibility with the other MSSs and easiness in simultaneous implementation.	Asif and Joost de Bruijn (2010), Heras-Saizarbitoria and Boiral (2013), Karapetrovic et al. (2010)
Difficulties	Understanding risk-based thinking, workers motivation, organizational culture, leadership commitment, team working and communication	Nargesi et al (2013), Bhuiyan and Alam (2005)	Different environmental laws, changing the company's culture, the benefits do not outweigh the necessary costs	Curkovic and Sroufe (2011), Santos et al. (2016)	Top management not committed, high certification costs, organizational culture.	Ghahramani (2016, 2017)	Employees' resistance to change, high cost of certification, inter-functional conflicts, lack of knowledge of the process,	Bernardo et al. (2012), Sampaio et al. (2012), Simon and Douglas (2013)

Table 5. Investigation approaches of ISO standards. Source: own elaboration

The Spanish Association for Standardization and Certification (AENOR) has given an answer to the market trend by launching the ‘‘Integrated Management Systems Certification’’, which can be used for organizations with an IMS for quality and environment (Jørgensen et al., 2006). On the other side, De Oliveira Matias and Coelho (2002) analyzed the common orientation found in the QMS based on ISO 9001, EMS based on ISO 14001 and OHSMS based on OHSAS 18001 from the advantages and disadvantages of integrating these systems, as opposed to the systems having independent management in a manufacturing company.

2.4 TPM and ISO 9001 Integration

TPM programs have been implemented and can be adopted by companies in different environments and within various types of organizations (Cua et al. 2001) and this affirmation also applies for ISO standards. After an extensive literature review about QMS, Kumar and Maiti (2017) identified TPM and ISO 9001 as ones of the most popular MSs being followed world-wide by various industries among others. Both TPM (Ireland and Dale, 2001) and ISO 9001 (ISO, 2015b) are based on the TQM principles: customer focus; leadership; engagement of people; process approach; improvement; evidence-based decision making; relationship management.

MSs standards suitable for integration are ruled by a risk identification approach (for the product/service quality, environment or health and safety) assuring control procedures to manage those risks, which place the risk concept as a possible integrator or pivot factor of the implementation of an IMS (Sampaio et al. 2012). Jørgensen et al. (2006) considered that the revisions of standards in ISO were creating a path towards more compatible management standards with cross-references and integration of system elements, which can reduce confusion and give administrative benefits related to the implementation and maintenance of the systems.

On the other hand, TPM has been subjected to further expansion to act as a world class performance improvement strategy rather than just a maintenance strategy (Eti et al. 2004). The concept of TPM enables an organization to acquire competitive strengths for competing in the global market. While this kind of knowledge explosion occurs through TPM, an expansion in the similar direction occurs at world class level in the form of obtaining ISO 9001 certification (Sivaram et al. 2012).

Thus, Sivaram et al. (2012) considered that it is essential to develop a model integrating TPM and ISO 9001:2008 standard for achieving synergy in continual improvement. And later, Sivaram et al. (2014) implied that TPM and ISO 9001 standard are built on main TQM principles. Hence, both TPM and ISO 9001 common elements were identified and integrated suitably in the Sivaram et al. (2014) TPM 9001:2008 model shown in Figure 1. In this model, a continual improvement process is described between the clauses of Management Responsibility, Resource Management, Product Realization and Measurement Analysis and Improvement. Each of the TPM pillars are assigned to each of these clauses based on their focused similarities and objectives.

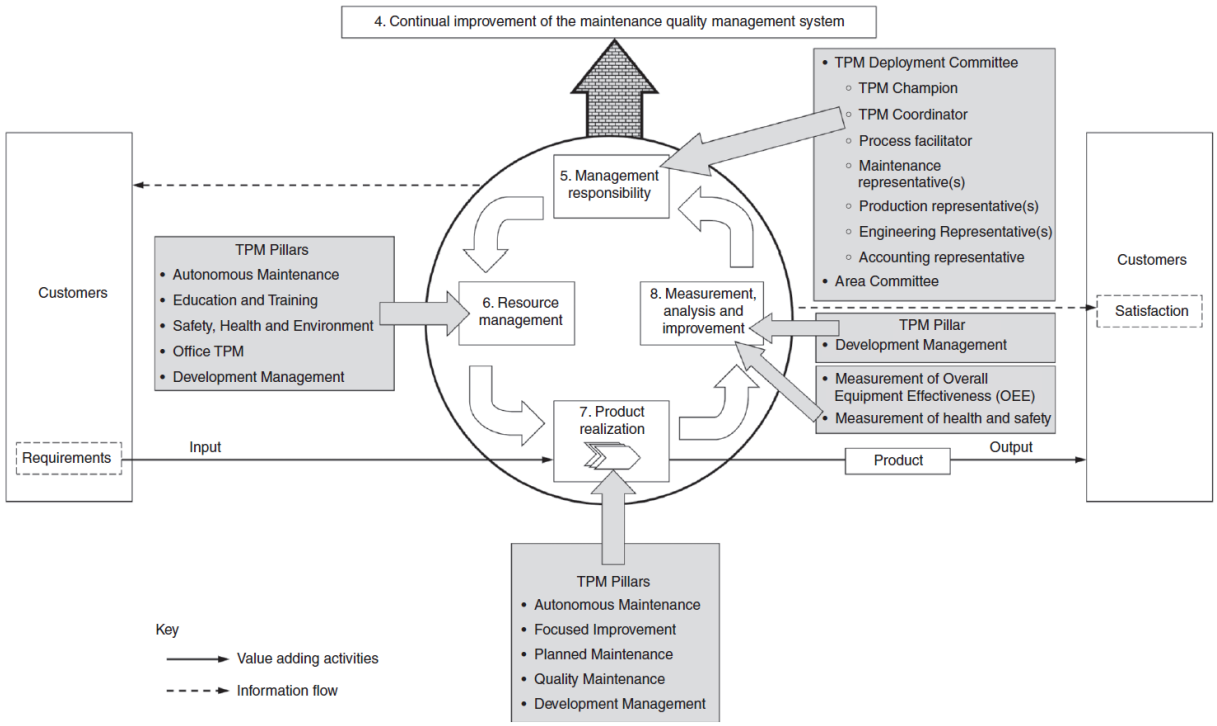

Figure. 1. TPM 9001:2008 model Source: Sivaram et al. (2014)

The TPM 9001:2008 model proposed fitted the elements of TPM in the clauses of ISO 9001:2008 standard by delineating the activities carried out to build each TPM pillar. These activities were infused to design TPM 9001:2008 model and were considered as "requirements". This fitting exercise was carried out to conceptualize the TPM 9001:2008 model. From this model, it was concluded that any company with an ISO 9001:2008 implementation can continue to retain its elements and can amend additional elements to implement TPM.

Through the literature review, the compatibility between TPM and ISO is presented, but with the new HLS, the question to be answered is if other ISO standards would also be compatible with TPM as well.

3. METHODOLOGY

This research is a qualitative study that consists on a literature review and a case study (see Figure 2). For this, the investigation follows a content analysis methodology, based on the initial TPM 9001:2008 model proposed by Sivaram et al. (2014) and the literature review about the ISO 14001, ISO 45001 and IMS. An integration approach is developed to present a new and updated proposal for the TPM 9001:2008 model.

The reviewing process was performed using academic data bases (such as Web of Science, Emerald Insight and Scopus), searching for the keywords: "Total Productive Maintenance",

"Integrated Management Systems", and "ISO Management Standards". The inclusion criteria included English language, article as the document type, and journals source type. After a basic pre-analysis, a total of 23 articles, 2 books and 3 official ISO standards were selected to determine the relationship between the literature and this research.

Then, based on the idea that the systematic compilation of management practices helps to shed light on current trends, to build new theories and to state relationships between practices and businesses outcomes (Flynn et al., 1990), the initial stage of a case of study in a multinational manufacturing company subsidiary is presented.

IMS demands significant changes within the organization, it is proposed to understand the process that companies face during this integration using the case study as an illustration. A case study is presented following the arguments of Yin (1994) that the analysis through case studies becomes appropriate for the study of the implementation of practices associated with changes, exploring the barriers of the phenomenon and integrating information from various resources.

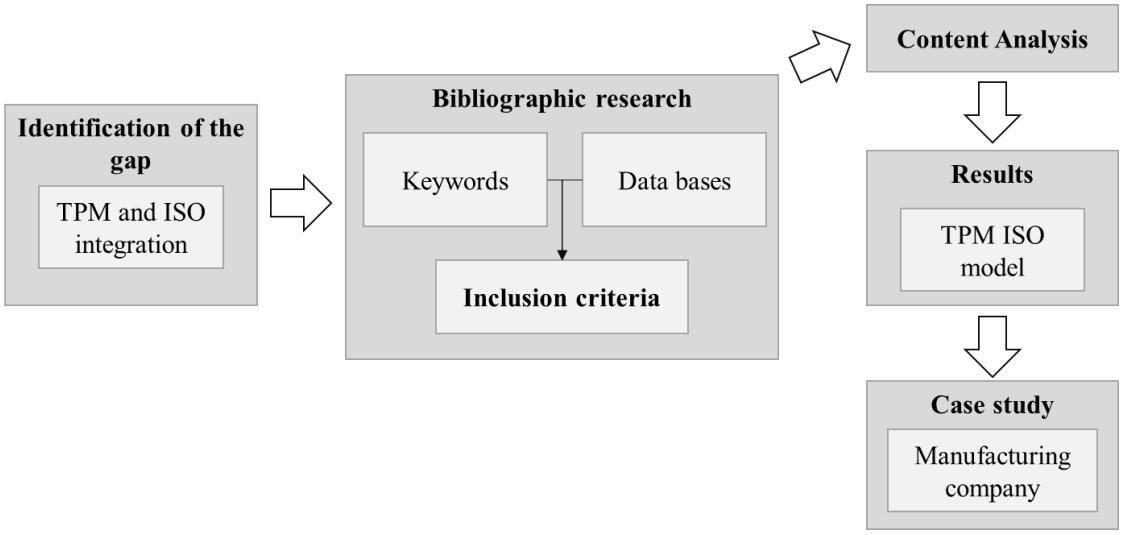

Figure 2. Developed methodology. Source: Own elaboration.

The case study is developed to obtain relevant information that would enable the characterization of the integration of the presented management systems in a multinational manufacturing organization by recommending the use of the proposed model. By a requirement previously established by the parent company, the subsidiary has ISO 9001:2015 standard certification. The plant had been certificated on ISO 9001 from 1999 and the initial motivations for its implementation were to have a differentiating factor in the market, create competitive advantages and demands from important clients. Later, a corporate requirement demanded to implement the ISO 14001:2015, so the implementation was done through an integration process with the HLS of the ISO 9001:2015. Also, the transition plan from OHSAS 18001 to ISO 45001 is on the agenda.

In 2017 a new strategy plan has been proposed by the company where a TPM implementation was required. The OEE was already being measured but the losses calculation needed to be defined.

Now, after 2 years after the implementation, data of the processes that reflected the impact of the integration between TPM and ISO standards was obtain for this investigation, such as OEE metrics, losses measures and practices addressed to QM, EM and OHSMS objectives assurance. In addition, telephone interviews were held with the quality assurance manager and the safety assurance manager due to their responsibility in the administration of the ISO 9001 and the safety policy respectively. The information and knowledge provided by them contributed to understand the impact of the integration process on the organization and the demands of the management systems.

4. RESULTS

The aim of this research is twofold. First, a new updated proposal for the TPM 9001:2018 by Sivaram et al. (2014) is presented as a model to integrate TPM with three function-specific ISO MSs based on the shared HLS. Second, to present a case of study applying the proposed model to start building a guideline of how companies could approach the integration of TPM with the ISO MS standards based on the implementation experience in a multinational manufacturing company.

4.1 Integrating TPM in ISO Standards

In the literature review made in Sivaram et al. (2012), the existence of connections between TPM and ISO 9001 from four angles were revealed as:

- Principle-based connections: with small group activities and continuous improvement;
- Element- and technique-based connections: with total employee involvement, leadership and management commitment, continuous improvement, training, and education;
- Connections through award-based quality frameworks: with the Malcolm Baldrige National Quality Award, the European Quality Award, and the Deming Prize;
- PDCA cycle-based connections: with the PDCA cycle used in the ISO standards to portray the clauses of the MS requirements.

The benefits of the TPM principles can be related to function-specific ISO MSs objectives (Duijm et al. 2008; Sivaram et al. 2013) as:

- Improvement of the end-product quality: related to ISO 9001.
- Improvement of environment and zero pollution: related to ISO 14001.
- Improvement of health and safety conditions in an organization which enhances employees' morale and societal benefits: related to OHSAS 18001 (for this investigation the ISO 45001 will be used).

These three ISO MSs contain the same basic disciplines and a general common structure. They all require the keeping of records, the need to continuous improvement by applying root cause analysis to corrective and preventive action, the requirement for internal system audits, the control of documentation and data, the issuing of policy statements (Wright, 2000).

The ISO MSs do not refer to compliance with an objective or with a particular result, so it is not a performance standard measuring the function specific objectives and due to that it is focused on standardized procedures, duties and roles, rather than measuring goals or outcomes (Heras-Saizarbitoria and Boiral, 2013). As in the "Performance Evaluation" clause states, the organization shall determine the methods for obtaining, monitoring and reviewing the results by using a variety of methods to maintain its knowledge and understanding of its compliance status. This is where TPM can be considered as an adequate alternative to provide that kind of measurable information.

Based on the Sivaram et al. (2012; 2013; 2014)'s approaches of TPM and ISO integration, and the literature review made in this investigation, the direct and indirect relationships between TPM pillar and the ISO clauses of 9001:2015, ISO 45001:2018 and ISO 14001:2015 by their common HLS are presented in Table 6. Likewise, the *"Performance Evaluation"* clause is supported by monitoring, measurement, analysis and evaluation of the OEE and losses. In addition, the compliance of each function-specific ISO MSs *"Planning"* and *"Operation"* clauses must be driven by the objectives defined by the management depending on the *"Context of the organization"*.

	Autonomous Maintenance	Planned Maintenance	Quality Maintenance	Focused Improvement	Development Management	Education & Training	Safety, Health &Environment	Office TPM
ISO 9001	INDIRECT: Clause 5 and 7	INDIRECT: Clause 7	DIRECT: Clause 1	DIRECT: Clause 10	DIRECT: Clause 7	DIRECT: Clause 7		DIRECT: Clause 5 and 7
ISO 45001	INDIRECT: Clause 5 and 7	INDIRECT: Clause 7		DIRECT: Clause 10	DIRECT: Clause 7	DIRECT: Clause 7	DIRECT: Clause 1	DIRECT: Clause 5 and 7
ISO 14001		INDIRECT: Clause 7		DIRECT: Clause 10	DIRECT: Clause 7	DIRECT: Clause 7	INDIRECT: Clause 4	DIRECT: Clause 5 and 7

Table 6. Direct and indirect relations between TPM Pillars and ISO standards. Source: own elaboration

The TPM pillar of "*Quality Maintenance"* aims to assure zero defect conditions in the production process by understanding and controlling the process interactions between manpower, material, machines and methods that could enable defects to occur. This has a strong relationship with the scope of the ISO 9001 where it is said that this standard is implemented in an organization when it needs to demonstrate its ability to consistently provide products and services that meet customer's and applicable statutory and regulatory requirements. This led to the reduction of the

"*Defect and rework loss"* from poor quality, rework, consumer complaints and the need for inspection are that is reduced.

The TPM pillar of "*Safety, Health and Environment"* implements a methodology to drive towards the achievement of zero accidents. It is important to note that this is not just safety related but covers zero accidents, zero overburden (physical and mental stress and strain on employees) and zero pollution (Sivaram et al., 2012). This has a strong relationship with the aim of the ISO 45001 which looks to provide a framework for managing OH&S risks by preventing work-related injury and ill health to workers and to provide safe and healthy workplaces. The safety of all workers takes big importance, a subject of matter because the comprehensive maintenance of machines and equipment become allies of the safety department (Maszke, 2019). This fusion pretends to completely eliminate risk situations and behaviors, accidents, damages resulting from machine failures or processes procedure deviations. This is an indirect but a clear approach to OH&S. Safety as a manufacturing priority has the following TPM considerations:

- Improve workplace environment.
- Realize zero accidents at workplace.
- Eliminate hazardous situations and behaviors.

Additionally for the environmental approach the pillar of "*Safety, Health and Environment"* suits on the ISO 14001 concept of better environmental performance can be achieved when environmental aspects are systematically identified and managed giving a major contribution to sustainability, through pollution prevention, improved environmental performance and complying with applicable laws (da Fonseca, 2015). With this on the table, it could be inferred that one of the goals of TPM is to create a safe workplace, with sustainable processes that will guarantee quality management.

The other six remaining pillar have a more conceptual effect in quality and safety, because TPM provides a comprehensive, life cycle approach, to equipment management that minimizes equipment failures, production defects, and accidents (Ahuja and Khamba, 2008a) by analyzing the modern principles of ISO for management systems as the Deming cycle of *''Plan-Do-Check-Act"* cycle and the concept of continuous improvement.

After the introduction of "*Autonomous Maintenance"* pillar, operators take care of machines by themselves without being ordered to. With the achievement of zero breakdowns, zero accidents and zero defects, operators get new confidence in their own abilities and the organizations also realize the importance of employee contributions towards the realization of manufacturing performance (Ahuja and Khamba, 2008b). This will fit in the "*Operation*" clause of ISO where the organization shall plan, implement, control and maintain the processes and the interactions needed to meet requirements of the MSs.

The TPM pillar "*Development Management"* aims at improving the existing process, to fit the employees into the improved system and initiating new maintenance improvement initiatives

(Sivaram et al. 2014). Hence the requirements of this pillar will be fulfilled through the implementation of the ISO standard clause named *"Planning"* where it is described that the organization shall consider the issues referred to its context and the needs of the interested parties requirements and determine the risks and opportunities that need to be addressed to: give assurance that the management system can achieve its intended results; enhance desirable effects; prevent, or reduce, undesired effects; achieve improvement. With this a reference to the *"Improvement"* clause where risks become a failure of the organization's systems, not the fault of the operator, and poor quality, safety or environment problems are no longer accepted as a normal occurrence making everyone in the organization responsible for maintaining optimal conditions and striving for the MSs objectives.

This lead to the "*Education and Training"* TPM pillar that can be fitted appropriately in the "*Support*" clause of ISO standards, with the sub-clause "*Competence*" describing that organizations shall determine the necessary competence of workers to ensure that they are competent on the basis of appropriate education, training, or experience. This internalization of the TPM concept and the additional training to develop competencies and fostering operator ownership to achieve autonomous maintenance lead to an aligning employees' mindset with organizational goals (Sivaram et al. 2014). Also, "*Office TPM*" pillar which concentrates on all areas that provide administrative and support functions in the organization will help to understand the losses measurement from these departments' perspective. The pillar ensures that all processes support the optimization of manufacturing processes and that they are completed at optimal cost (Ahuja and Khamba, 2008a). This was facilitated by the *"Leadership"* and *"Internal Audit"* clauses that demonstrated the commitment of the top management reviewing the organization's management systems to ensure its continuing suitability, adequacy, effectiveness and alignment with the strategic direction of the organization.

The TPM performance is measured by the Overall Equipment Effectiveness (OEE) to determine the deficiencies and the activities required for improving the operational performance that will clear the path to the losses reduction (Sivaram et al. 2012). Hence OEE and losses appropriate measures for measuring operational and process performance can be fitted into *"Performance Evaluation"* clause. However, OEE is not incorporated with component measuring accidents or variables relating to health and safety or environment. Therefore, any suitable measure for measuring health and safety performance is/are to be added for achieving the aims of the ISO 14001 and ISO 45001. For example in the case study of Maszke (2019) the measure of the safety level was made by the number of audits carried out by a leader, the number of incidents based on behaviors or risk situations reported by employees or additional OH&S trainings. In addition, the *"Internal Audit"* sub-clause can direct the measurements to provide information on whether the management systems conforms to the organization's own requirements for its QM, EM and OH&S management systems, including the policies and objectives that are effectively implemented and maintained. Therefore, the TPM pillar *"Focused Improvement"* pillar can be fitted in the *"Improvement"* clause by interpreting the *"Corrective Actions"* of nonconformities promoting the

participation of workers in implementing actions for the continual improvement of the management systems. This can be integrated with use of structured Root Cause Analysis trough work teams and small group activities to achieve incremental improvements (Ahuja and Khamba, 2008a).

In the same page, the "*Planned Maintenance*" pillar involves evaluating current maintenance performance and costs to set the focus for improvement (Adesta et al. 2018). The team identify the optimum approach to maintaining the equipment, starting with a Periodic Maintenance (Time-Based Maintenance) system before introducing Predictive Maintenance (Condition-Based Maintenance) systems where they are appropriate and cost effective. Finally, the team drive continuous improvement and changes of the processes, directed to achieve the aims of the QM, OH&S and EM by eliminating possible risks for defects, environmental impact and unsafe conditions assuring machine reliability. As the contents of the sub-clauses "*Awareness*", "*Communication*" and "*Documented information*" deal with the management of resources and infrastructure, the TPM pillars "*Autonomous Maintenance*", "*Education and Training*"; "*Office TPM*" and "*Safety, Health and Environment*" can be appropriately fitted in the "*Support*" clause of ISO 9001:2015 standard.

In the Figure 3 an updated model based on Sivaram et al. (2014)'s model is proposed, based on the PDCA cycle and the high-level structure (HLS) that can be applied to picture the IMS as a whole. This allowed to present the TPM ISO model, which shows the integration approach by the above mentioned direct and indirect relationships.

According to Ahuja and Khamba(2008a), in order to realize the true potential of TPM and ensure successful TPM implementation, TPM goals and objectives need to be fully integrated into the strategic and business plans of the organizations, because TPM affects the entire organization, and is not limited to production. The first course of action is to establish a strategic direction for TPM. This success factor view shares big similarities with the ISO clause number 4 "*Context of the Organization"* where it is stated that the implementation of an OH&S management system is a strategic and operational decision for an organization. A most generalized participation is demanded continuing arguing that the success of the OH&S management system depends on leadership and commitment from all levels and functions of the organization. At this point it is clear that no management system can work property without a strategic plan to guarantee that all members of the organization must understand that all processes need to be aligned with the aim of the standard described in the *"Leadership"* clause also supported in the *"Support"* clause.

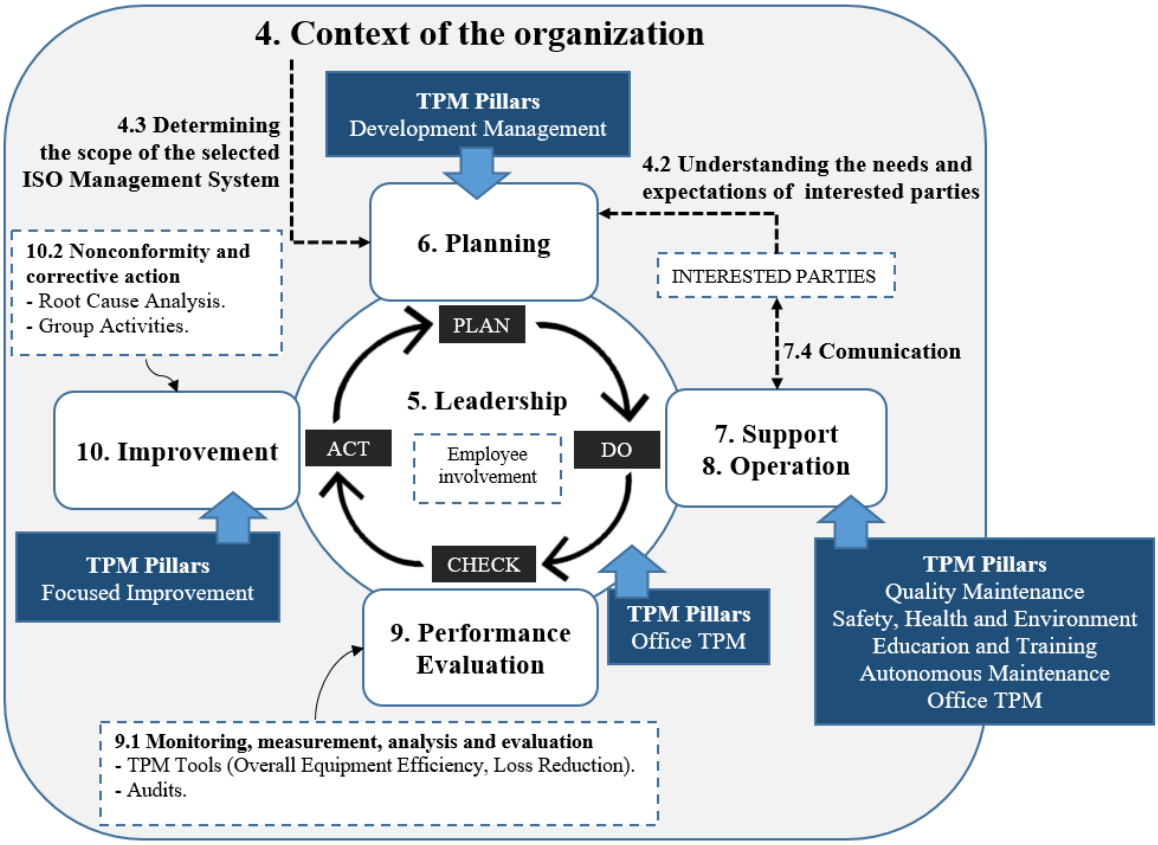

Figure 3. TPM ISO model. Source: Own elaboration.

4.2 Case Study Proposal

According to Karapetrovic and Jonker (2003), there is not one best methodology for integrating management systems and it is not possible to develop a methodology that will work in all cases because both the objectives (ending points) and initial conditions (starting points) on the path to an IMS are different for each company. Sivaram et al. (2014) considered that the practical compatibility of the model will have to be checked by implementing it in several types of organizations. This addresses the question of "how to build an own integrated MS proposal that fit the organization needs?"

This case is a demonstration of how a multinational company could assume the integration approach based on the context of the organization. In this case an approach focused on the *"Performance Evaluation"* and *"Improvement"* clauses of the ISO will be described from a case of a subsidiary paper mill plant of a multinational company by the TPM measuring tools of OEE and Losses Reduction based on the recommended models of integration by Jørgensen et al. (2006):

- Partial integration. Integration of some common procedures from the management systems;

- Total integration. This model goes beyond common procedures and involves an integration based on a process approach and continuous improvement.

After the interview with the quality assurance manager of the plant, the partial integration model was recommended to describe the interaction between TPM and the ISO standards due to there is still some distance to achieve a total integration. The metrics were the determined methods for obtaining, monitoring and reviewing the standard ninth clause of Performance Evaluation. The partial integration process based on the TPM ISO model was synthetized in 4 Phases: internalization, performance scenario, reporting and audit, described below.

Phase 1 (Internalization): Training to achieve the internalization of the TPM philosophy and ensure the involvement of workers with education programs by creating the individual and group values, attitudes, managerial practices, perceptions, competencies and patterns of activities that determine the commitment to TPM. The quality knowledge demand was already done due to the impact of the *"Support"* clause and the sub-clauses of "*competence", "awareness" and "communication"* of the previous ISO 9001 and ISO 14001 implementation by ensuring that the employees were competent with appropriate education, training and experience. Thus, employees were conscious of their contribution to the effectiveness of the management system, including the benefits of improved performance. This was one of the main factors to achieve a positive involvement. Other factors to achieve a proper assimilation of the TPM demands were the employees' understanding of the "*resources"* sub-clause.

In Figure 4 the engagement rate of workers is shown to follow up the commitment of the employees. The increasing tendency evidenced during the TPM implementation is also attributed to the development of the *"Leadership"* clause by engaging, directing and supporting employees to contribute to the effectiveness of the quality management system. This allowed to support other relevant management roles responsibility in all areas.

Engagement was determined by:

- Attend the engagement meetings (Including Safety) and contribute to the meeting.
- Participation in 5's or Management Development events.
- Complete an improvement suggestion as part of the Focused Improvement Pillar.
- Participant in an improvement project with documentation, data collection, or analysis.
- Participation in the development of procedures for adequate operation of equipment or safety procedures.
- Participation in the investigation of root causes analysis of customer complaints (quality), risk situation incidents (safety), or elaboration of an equipment failure analysis.
- Complete a programed audit.

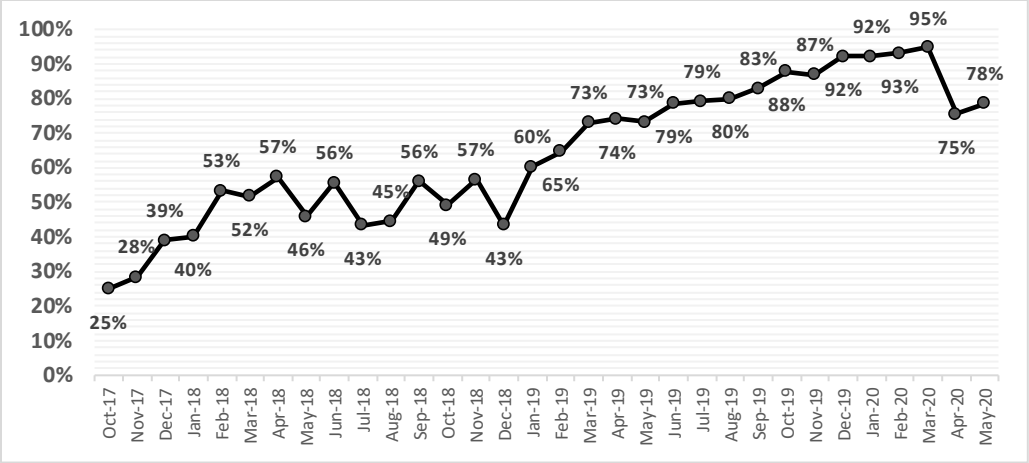

Figure 4. Engagement on TPM activities. Source: Company metrics.

Phase 2 (Performance scenario): Pillars implementation and construction of a base line of the losses in order to create a performance scenario. For this, the company headquarters determined that just 7 of the 16 major losses, explained in the literature review (see Table 3), were required to be measured: breakdown/failure, set-up and adjustment, reduced speed loss, idling and minor stoppage loss, defect and rework loss, start-up loss, planned shutdown loss, yield loss, energy loss. The base line of the losses was built to establish a reference for the goals to accomplish. Each month all the losses were calculated and totalized. Base line was constructed during the first year of implementation (November 2017 to August 2018) by an average of the totalized losses during this period and the improvement goal was to reduce the base line average of the total losses by a 5%. The decreasing of the losses was directed by the *"Improvement"* clause of the ISO. Examples of how the company determined opportunities for improvement and implemented the necessary actions included capital projects, pareto analysis, root causes analysis, process innovations and re-organization. This was achieved according to the ISO sub-clauses *"Nonconformity and corrective action"* and *"Continual Improvement"*. The tendency of losses shown in Figure 5 makes evident that the improvement process was perceived in January 2019 with a considerable reduction of the sum of all losses. The variation of the losses is presented by the percentile difference from the established goal.

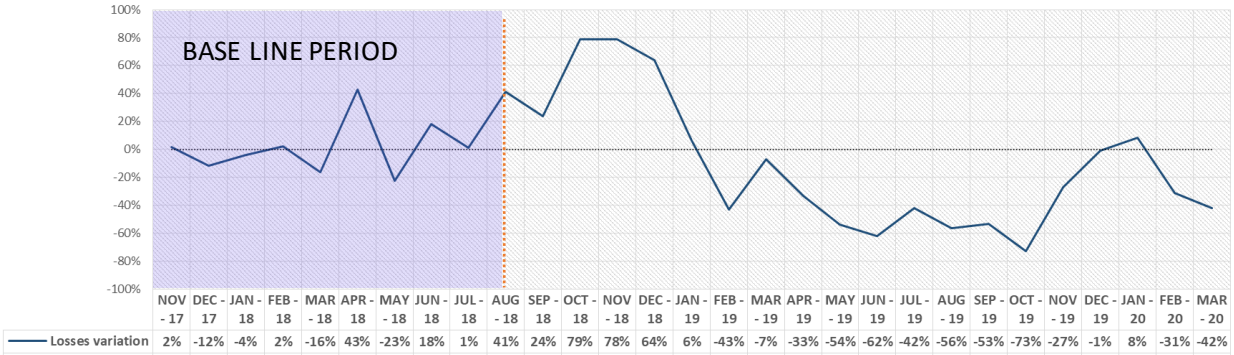

Figure 5. Total losses variation with reference to the base line. Source: Company metrics.

The OEE metric tendency shown in Figure 6 is also part of the "*Performance Evaluation*" and it is assumed as a consistent metric. For this reason, its measurement is more focused on the corrective actions that cause negative variations which usually leads to simple root cause analysis of specific day-by-day problems approached by small group activities that ensure the participation of the workers.

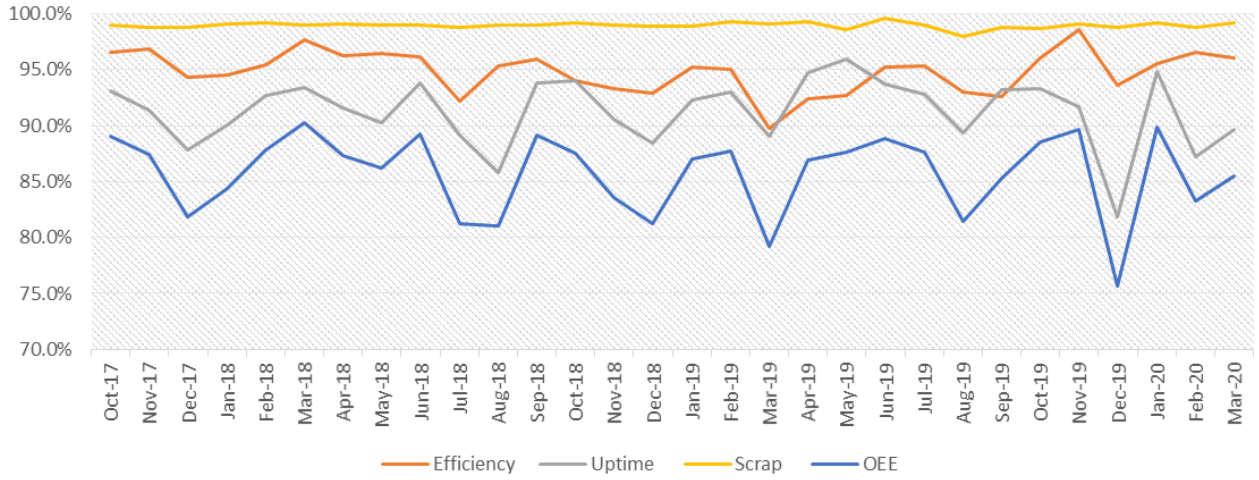

Figure 6. OEE metric tendency. Source: Company metrics.

For Occupational Health and Safety, metrics as safety audits, risk observation reports and root cause analysis for risk conditions are tracked and documented. Goals are established by the number of reports, completion of audits that evaluate progress of corrective action on non-conformities based on safety gap analysis. Leaders are encouraged through quantitative goals to make risk behavioral observations to employees that lead to hazards identifications in order to keep safety culture and create actions to address risks, hazards and opportunities. This is linked to the *"Planning"* clause of the ISO 45001 that help the development of the "*Safety, Health &Environment"* TPM pillar initiatives.

Phase 3 (Reporting): Reports generation with the information demanded in a standardized manner. One of the main benefits perceive of the integration with the ISO standard was the standardized way of reporting. It allowed comparing different plant locations within each other to identify the best performance and create a sharing information culture. This led to a benchmarking culture to copy the good practices and explain the problems that create an increase or decreasing of the losses in different plants. There were generally parallel practices, such as audits, document control, objectives and metrics systems that were difficult to integrate. However, the *"Documented Information"* sub-clause inside the *"Support"* clause of the ISO was a way to face this issues due to the majority of documented information necessary for the effectiveness of the ISO 9001 and the ISO 14001 was well determined and this allowed to identify the relationships and duplicates of the information to create a single reporting process for the determined measures.

Phase 4 (Audits): Audits to ensure the Plan-Do-Check-Act cycle. The audits became a tool for evaluating the progress of the TPM initiatives based on the 9.2 "Internal Audit" sub-clause for the "Performance Evaluation". After the training phase everyone in the company from workshop operators to administrative staff should have the competence to make internal audits. Cross areas audits were recommended to prevent manipulation of the information. Audit do not create improvement by itself but it sure evaluate the progress that will evidence the expected benefits of the integration.

Some of the main benefits that Sivaram et al. (2012) defined are perceived in the case study with the TPM ISO model, conforming the *"Performance evaluation"* and *"Continual improvement"* clauses, can be defined with TPM initiatives shown in the proposed model as:

- Losses reduction: improvements in cost, delivery, flexibility.
- OEE: improvements in productivity and quality.
- Employee engagement: increases in employee morale, safety and work environment improvement.

These benefits could collectively enhance the competitive advantage of the organization. Other tacit benefits expressed by the managers were the creation of a sense of ownership among the operators through the interaction of the *"Support"* clause based on the fulfillment of the sub-clause *"Competence"* with the TPM pillars of *Autonomous Maintenance* and *Education and Training*, as it is shown in the model. This was achieved through employee education, training and the creation of multi-skilling of employees.

5. CONCLUSIONS

Since management systems have been evolving to achieve business performance excellence, the purpose of this research is twofold. First, to propose the TPM ISO model that integrates TPM with three ISO function-specific MSs, and second, to apply the proposed model in a company. This is a response of worldwide organizations tendency to implement a combination of multiple MSs, in order to found the flexibility capabilities described by Kumar and Maiti (2017) to harmonize the differing requirements of function-specific MSSs when integrating them with company objectives. The presented case study is an evidence of the partial integration process mentioned by Jørgensen et al. (2006) to show the developed practices of a manufacturing company to deal with the challenges of IMS by using the proposed model. The case study is an answer to Sivaram et al. (2014) recommendation of studying the implementation of the new and updated ISO TPM model in typical manufacturing companies.

The integration of TPM and ISO standards through the proposed TPM ISO model is a strategic and operational decision for an organization become a requirement for the sustenance of organizations. The phases described in the case study go from the involvement of all employees in the organization to the creation of an organizational culture that engages in a continuous cycle

of self-evaluation, correction and improvement of operations and processes through management leadership and commitment. The common factors identified for a successful implementation of IMS depends on leadership, commitment and participation from all levels and functions of the organization. These built a determinant approach and, as it appears in the proposed model, it should be the major concern for companies trying to create a functional integrated system and reach sustenance of organizations.

It is clear that the HLS of the ISO standards created a common structure that facilitates the integration approach. The proposed TPM ISO model gives the opportunity to identify the qualitative options that will facilitate the interpretation of improvement through the TPM elements such as OEE and losses reduction. Organizations receive ISO certifications after demonstrating to a third-party that they have mapped their operating processes associated with the function-specific requirements of the MSs and that they conform and adhere to documented processes of continuous improvement. TPM principles contribute to the ISO standards in this way due to the *"Evaluation Performance"* and *"Audit"* clauses give the freedom to companies to determine how their processes are going to be measured. Thus, integrating TPM with ISO becomes complementary, consequentially to Ahuja and Khamba (2008c), thanks to its qualitative approach to track the development of the integrated objectives into the strategic and business plans of the organizations.

The presented case study allows describing the way of how a company handles the challenge of integration, and what conceptual connection should be identified between the MSs in order to perceive the benefits perceived inside the company such as facilitation of continuous improvement, simplification of the certification process, decrease of complexity of internal management, and decrease of paper work (Zeng et al. 2011). The evolution of the integration process in the case study follows two of the three dimensions described by Rocha et al. (2007): *assimilation* and *augmentation*. This is how the company enhanced its resources by applying the ISO clause *"Support"* to promote synergies between the MSs by developing a more in-depth understanding in specific issues through the TPM pillars initiatives.

One of the most notable contribution of this investigation is to show companies the customization possibilities for the integration of MSs based on the organization context and their manufacturing environment. The identification of the relationships between the ISO clauses and TPM pillars initiatives is a step to their integration that helps to prevent parallel activities and the additional workload perception of employees as described by Sivaram et al. (2013). Thus, the model proposed could be considered as an integration methodology, contributing to the existing literature on this integration aspect, providing also an applied example. Another contribution is the approach of the environmental aspects of the ISO 14001 on TPM due to specific contributions to this topic are now limited in the pillars. Thus, it contributes to make TPM and the resulting integration, a more sustainable practice.

This research provides a framework that could be useful for managers that are facing the challenges focused on the sustenance of IMSs inside their organizations' processes as the means to improve

quality, environmental and organizational health and safety impact. This could lead to facilitate organizations achieving competitive strengths and visualize tangible benefits of the continuous improvement. Thus, the presented model and case study could bring useful practices that can be developed to enhance the practicality of implementing TPM through ISO function-specific MSs.

There are some limitations that should be considered. For instance, the generalization of the case study should not be done because it reflects only the context of one type of organization in a single manufacturing framework. The results of the case study were developed to consider some elements of the theoretical framework and needs of a subsidiary of a multinational company by identifying good practices, challenges and strategies adopted in the integration of TPM and ISO MSs. Thus, the set of 4 phases proposed are a description of this specific case and they would have to be applied in more companies to be extrapolated, possibly with significant changes. Future research could be done as a respond to these limitations by encouraging more case studies that could contrast the model and validate its impact on the IMS literature.

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