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Information Management in Physical Asset Management

Ana Carolina Gandini Panegossi
Federal Institute of Sao Paulo (IFSP) – Matao Campus, Matao, Sao Paulo, Brazil.
Doctoral student in the Regional Development and Environment Program of the University of Araraquara (UNIARA), Araraquara, Sao Paulo, Brazil
carolinagandini@uol.com.br; carolina.panegossi@ifsp.edu.br;

Ethel Cristina Chiari da Silva
University of Araraquara (UNIARA), Araraquara, Sao Paulo, Brazil
e-chiari@uol.com.br

Marcus Cesar Avezum Alves de Castro
Sao Paulo State University (UNESP), Rio Claro, Sao Paulo, Brazil
marcus.castro@unesp.br

Abstract

Asset management studies have shown that access to quality information is one of the main critical success factors for asset management standards implementation and effective decision-making. However, studies also show that quality asset data have been a barrier to accessing quality information because several departments process data collection and register, and rarely are integration and connection in them. The introduction of artificial intelligence machines is the latest trend in the manufacturing industry. Its primary motivation is to ensure reliable, complete data and real-time information linking all parts or elements of the value chain. Through a literature review, this research aimed to understand the role of information in physical asset management, why many researchers consider it a key dimension in manufacturing companies, and how to be information management with 4.0 machines introduction. As a result, this study suggests that it is possible to compile quality data with proper training and through ISO 55001 information requirements guidelines. However, this research also indicates that, despite currently being able to count on real-time information with 4.0 machine introduction, the companies are not prepared for such disruption. Just as the successful ISO 55001 requirements implementation is directly related to corporate culture, the new technologies acquisition and data use also depend on organizational factors. Therefore, before engaging its efforts and investing its capital in acquiring 4.0 equipment, the companies need to continue investing in its best assets: the people who will know how to use the benefits.

Keywords
Asset management, Asset data, Asset information, ISO 55001, Industry 4.0.

1. Introduction

The most published literature in Asset Management (AM) references the importance of data and information management. It is a significant concern for organizations dealing with substantial problems and complex physical asset portfolios, as AM performance depends heavily on the quality and availability of asset data and information (Glassonet al. 2017). The data refers to an elementary description of things, events, activities, and transactions recorded, classified, and stored but not organized to convey any specific meaning. The data has no real meaning outside the context and requires an association with something else. Information is data in context, that is, usable data. Information can be considered systematically organized data with meaning and value to the recipient (Spruit and Linden 2019). Data quality problems are prevalent in companies of all sizes and have been researched for many years and used interchangeably with information quality. Inaccurate data can create chain effects that affect many activities and businesses. As data is also an asset of an organization, the value of data quality must be emphasized in the different hierarchies (Zhang and Xiang 2015). For the data not to be erroneous, attention is needed to the main problems that can affect their quality, such as the inappropriate assignment of work, the inadequate or confusing

identification of the work, and the inability to identify suspensions or hours used by physical assets, among others (Ho et al. 2014).

Good asset management decisions involve balancing costs, risks, and performance. Furthermore, it means achieving maximum performance at the lowest costs, mitigating all the risks that each asset may present (Ho et al. 2014) since the objective of any asset is to add value to the organization and stakeholders (ISO 2014a). Therefore, knowledge of the condition of the assets allows companies to make intelligent decisions, and monitoring systems are always the fundamental facilitator to knowing the precise conditions of the assets. However, sometimes the information provided by these systems is not used correctly; either because it does not reach the appropriate places to be used, because the monitoring system is isolated from the management systems, or because the system is inoperative and nobody has noticed it (Bautista 2019).

The primary motivation behind the fourth industrial revolution is to ensure the adequate availability of reliable, complete data and real-time information linking all parts or elements of the value chain. Furthermore, the interconnection between these components - including people, devices, and things - promotes highly organized, dynamic, and simplified value-adding flows (Alqahtaniet al. 2019). Introducing the Industry 4.0 machines also brings opportunities for automation, process optimization, asset management, predictive maintenance, and, consequently, reduced downtime and thus increased revenue (Bhandari et al. 2020). However, new technologies implementation is only part of the picture since studies point to the importance of the organizational factors in developing strategies to implement Industry 4.0 in the maintenance and AM. In other words, many organizations do not understand that organizational factors are critical in achieving digital transformation success (Pedersen and Schjølberg 2020).

1.1 Objectives

Thus, this study aimed to carry out a bibliographic review of the role of information in physical asset management, why many researchers consider it a key dimension in manufacturing companies, and how to be information management with 4.0 machines introduction.

2. Literature Review

Owners of physical assets must make a series of decisions to effectively and efficiently manage those assets. Each decision is fully robust only when information can provide objective evidence about all aspects of the asset and the Asset Management System (AMS) (King and Crowley-Sweet 2014). Despite the large amounts of data increasingly collected to support decision-making processes in AM, the challenge is finding the best way to use these fragmented and disorganized data sets. It is essential to use and combine all relevant data, both technical and economic, to create new business knowledge to support effective decision-making, in different contexts, in different situations, and at diverse levels of decision-making: strategic, tactical, and operational (Kinnunen et al. 2016). Although data can be collected helpfully and validly, they need improvement, particularly the link, or the lack of, between financial and asset data management systems (Arthur et al. 2016).

Accordingly to Polenghi et al. (2019a), asset managementis gaining more and more attention among researchers and practitioners as it aims to create an integrated and holistic methodology to manage physical assets. This methodology is based on AM's fundamentals: 1.asset control levels; 2. asset lifecycle stages; 3. AM principles.

1. For El-Akruti et al. (2013), the AM activities can be classified into hierarchical organizational management levels. Moreover, asset control levels can be defined according to the planning horizon as follows:
    - Strategic (highest level),
    - Tactical (mid-level),
    - Operational (low level).
2. A typical asset's complete "cradle-to-grave" life can be divided into three interdependent stages. Its lifecycle stages are (Ouertani et al., 2008):
    - Beginning of Life (BOL): which involves the design and creation (manufacture) of the asset;
    - Middle-of-Life (MOL): when the asset moves into the usage stage when it provides its intended service to its user and requests services from the user in the form of maintenance, upgrade;
    - End-of-Life (EOL): when the asset is eventually retired from operation.

3. The company's ability to implement AM consists of the capability to integrate, in its organization, the two main dimensions mentioned above, into a robust and clearly defined AM system. Besides the asset lifecycle stages and the asset control levels, four principles can be considered. AM decision-making must introduce them, too (Roda and Macchi 2016; Polenghi et al. 2019a):
    - Life cycle orientation;
    - System orientation;
    - Risk orientation;
    - Value orientation.

Figure 1 presents asset control levels.

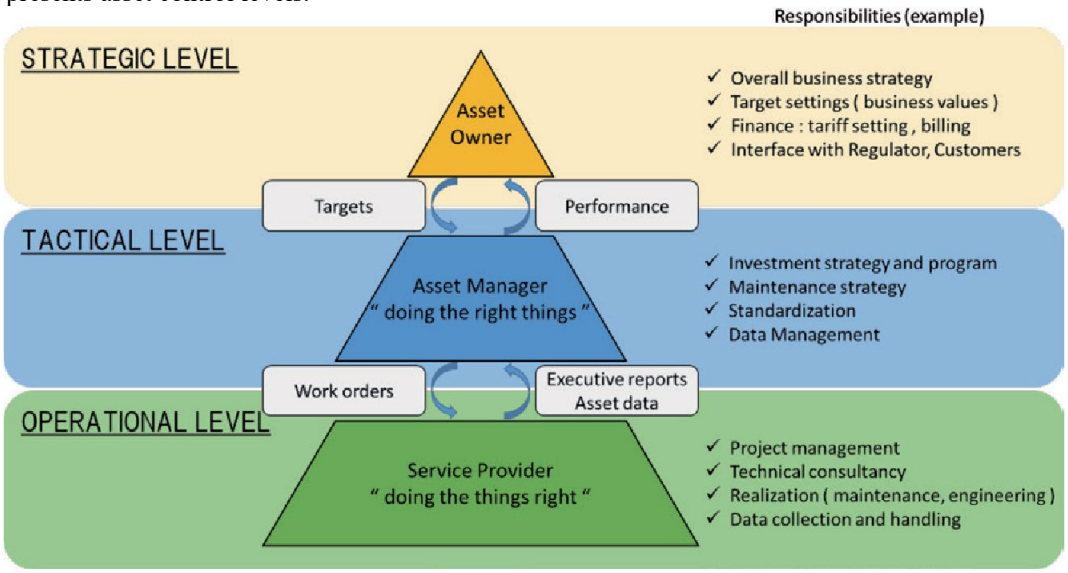

Figure 1. Asset control levels
Source: International Electrotechnical Commission (2015, p. 27).

Figure 2 exposes the lifecycle of a typical asset.

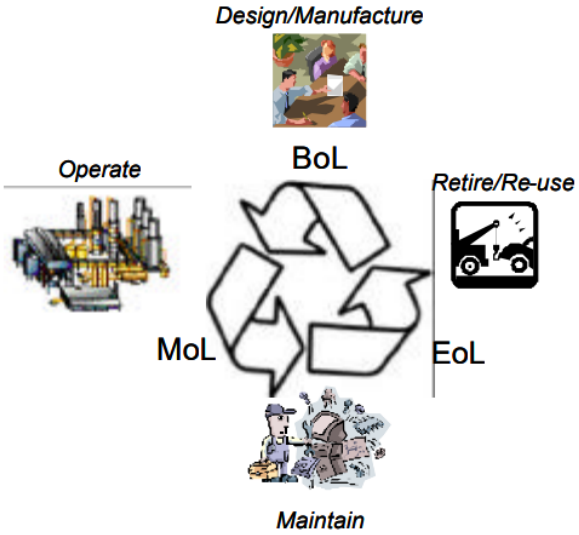

Figure 2. "Cradle-to-grave" asset lifecycle
Source: Ouertani et al. (2008, p. 30).

Figure 3 shows asset lifecycle stages, as well as their related decisions.

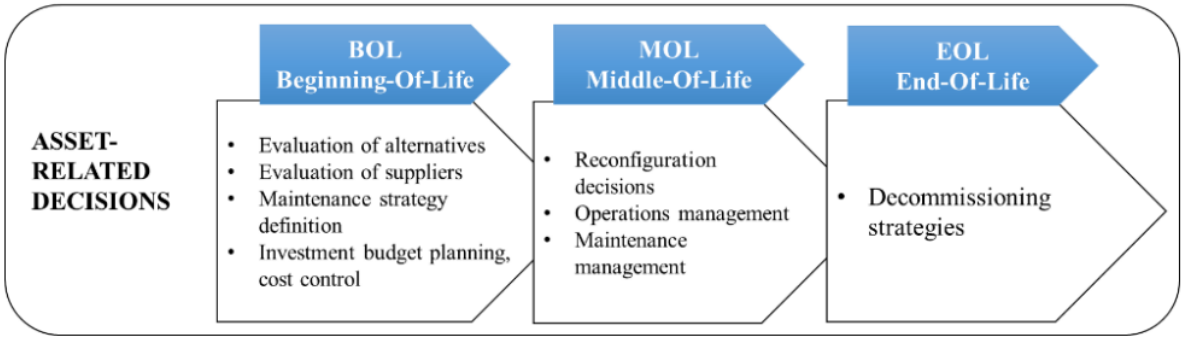

Figure 3. Asset lifecycle stages and related decisions
Source: Polenghi et al. 2019.

Figure 4 brings the four AM principles integrated into the other two dimensions.

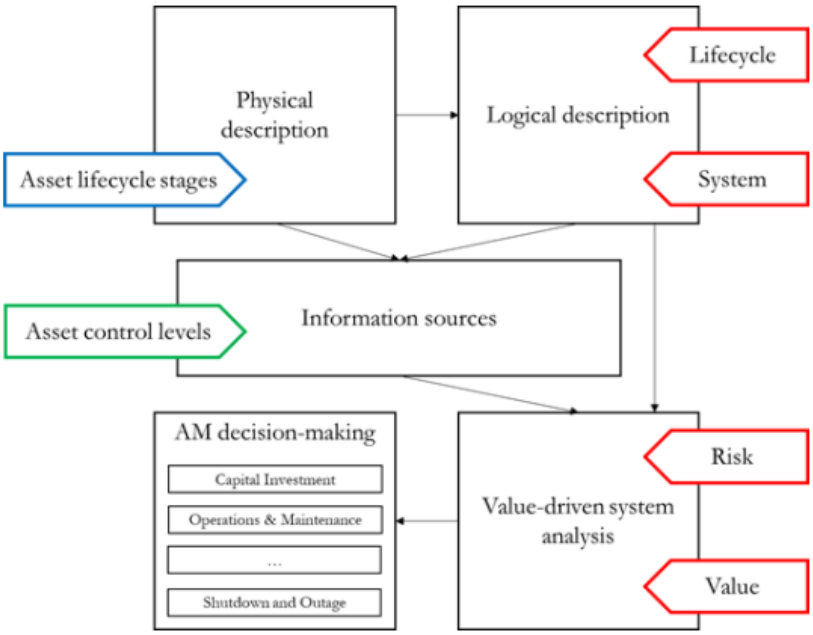

Figure 4. AM principles
Source: Polenghi et al. (2019c, p. 286).

ForPolenghi et al. (2019a), information and data become substantial in AM decision-making since every decision needs adequate information and data to support and respect AM's fundamentals. For the authors, it is still possible to relate the information and data criticality to three main levels, which are identified how:

- Data collection (level about the data gathering activities from the shop floor and the storage in databases);
- Data to information transformation (this level promotes asset-related decisions by transforming raw data into useful information that may be already used to make local decisions. It could support the first decision-making, but not in an integrated and holistic view as the one of AM);
- Information management and integration (this level enhances the AM decision-making process by adequately managing and integrating the information. The decision-maker is helped in choosing the best option, relying on AM fundamentals).

Figure 5 displays the information and data levels.

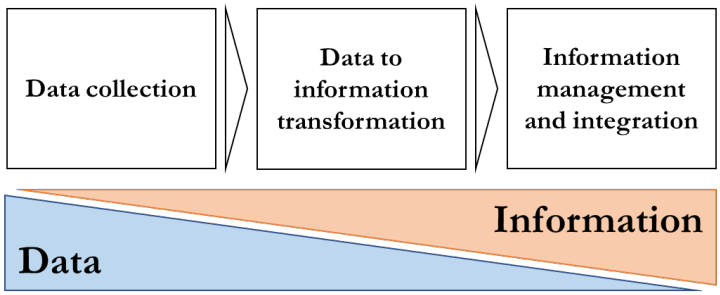

Figure 5. Information and data levels
Source: Polenghi et al. 2019.

In the same way, Ahonen et al.(2021) mention that modern asset lifecycle management needs to deal with a mix of strategic-level information to define correct allocations, timing, and investment resources. Tactical-level information for allocating maintenance tasks based on their criticality, maintenance windows, and, for example, production schedules. Operational-level information for effective implementation of daily maintenance.

In a survey carried out by professionals in the field on the evaluation and classification of the importance of the 39 principal subjects in AM according to GFMAM (Global Forum on Maintenance and Asset Management), the group of professionals with more than five years of experience valued much higher the subjects "asset information systems" and "competence management" than the group with less experienced professionals. The research concluded that the most experienced group probably has practical experience of the value of a good information system for managing assets and developing AM competency (Visser and Botha 2015). Another research(Polenghi et al. 2019b) identified and mapped the sources of risk in AM addressed in the literature:equipment,information management, human factor,organizational architecture, and suppliers. Taking the manufacturing sector as a reference, information management was considered the main source of risk when making asset decisions.

Effective information management results in (Glassonet al. 2017) :

- Better data quality;
- Better service quality;
- Greater capacity to respond to changes;
- Cost savings;
- Improvements in work cooperative work;
- Provision of coordinated services between organizations;
- Better-equipped employees to make decisions;
- Faster and more economical system development.

Data quality is critical to business operations and must be guaranteed to be reliable for the analysis. Organizations commonly use data quality dimensions: accuracy, relevance, timeliness, and reliability. The quality of the data is context-specific. The data is of high quality if different groups of users well understand its meanings. Information quality is defined as desirable characteristics of the results of the system, such as reports, for example. It must have precision, conciseness, integrity, comprehensibility, timeliness, opportunity, and usability (Zhang and Xiang 2015). Companies should look for unified asset information management systems since information is spread across diverse systems and behind different organizational barriers (Hanski et al. 2015). Both financial and non-financial areas are likely sources of necessary data on assets. The organization must ensure that all areas strive to collaborate in data collection, making access to data available to the right people (ISO 2019).

The management of physical assets, which also refers to the management of productive equipment, requires an information system to capture data that can be used to support decision-making. It becomes a vital part of business management for many organizations, especially when the capital investment in equipment is significant. The productivity/sustainability of the asset is fundamental to the competitive capacity of the business; that is, the productive use of these assets provides the value that underpins all of the organization's assets (Alfatih et al. 2015).

Therefore, an organization must treat the information in asset management as one of its main assets. It needs a simple process to decide what information is necessary to document and document it in a single database for the entire organization (Pais et al. 2019).

Physical assets management requires the cooperation of various stakeholders from different departments. Each has different interests, points of view, and perspectives; their performance is influenced by and depends on people. Managing human competencies in organizations increases competitive advantage, innovation, and effectiveness (Al Marzooqiet al. 2018). AM is multidisciplinary and complex because it requires well-established and controlled processes, trained human resources, effective information management, integration between technical and managerial areas, and highly committed leadership (Lima and Costa 2019). Human factors, such as leadership, motivation, and culture are critical to the success of optimized management and are supported by physical assets (Assis 2013).

In implementing ISO 55001, the organization must ensure that the documented information has an appropriate and relevant identification, description, and format. The data quality attributes for availability and protection are addressed. It is necessary to obtain information on the monitoring, measurement, analysis, and evaluation of the performance of assets, non-conformities or incidents, any subsequent actions of decision making, and the results of any corrective action. Implementing ISO 55001 will likely create a large amount of asset data, potentially higher quality than before standardization (Hodkiewicz 2015).

The ISO 55001 requirement related to asset information and relevant to this study is "information requirements," included in "support" of the standard. "Information requirements" refers to the availability and quality of information, vitals for all aspects of asset management (ISO 2018).Therefore, the organization must determine the information requirements considering (ISO 2014b):

- The significance of the identified risks;
- Roles and responsibilities;
- The processes, procedures, and activities;
- The exchange of information with interested parties;
- The impact of quality, availability, and information management on decision making.

The organization must determine(ISO 2014b):

- The requirements for the attributes of the identified information;
- The quality requirements for that information;
- How and when they should be collected, analyzed, and evaluated;
- Specify, implement and maintain the processes to manage them;
- The organization must also determine the requirements for aligning AM financial and non-financial terminology;
- The organization must ensure consistency and traceability between technical and financial data.

In a survey on the limitations in the implementation of the requirements of ISO 55001 in Polish enterprises, the main barriers found related to asset information were (Nowakowski et al. 2017):

- ❖ No reporting systems to support the collection of data relevant for the process control and improvement of the organization;
- ❖ Employee knowledge is owned by them and not recorded in enterprise databases;
- ❖ The lack of identified information needs of managers involved in the decision-making process).

With exponential data growth, companies face unprecedented challenges, but they also face numerous opportunities for competitive growth (Zhang and Xiang 2015).Because of AM data's increasing volume, complexity, and strategic importance, it is no longer desirable or feasible for each department to manage this data independently or create its data analysis resources. Advances in technology, such as the BI (Business Intelligence) tool, have revolutionized data and performance reporting so that users with limited IT (Information Technology) experience can extract data and develop high-impact visuals for performance reports (Ramamurthy 2016). The two most essential characteristics of Industry 4.0 are in-formatting using cyber-physical systems and the concept of the Internet of Things (IoT), adopted to produce smart factories (Kumar and Galar 2017). The IoT employs several sensors on a manufacturing assembly line for monitoring. The data retrieved from the sensors provides valuable insights to plant managers for

better tracking their assets, better inventory management, greater situational awareness, more opportunity, efficiency, cost reduction, and new insights for predictive maintenance, leading to reduced downtime (Bhandari et al. 2020).
Evidence-based asset management aims to make correct decisions and optimize asset management processes with the best information available. Asset information systems are widely applied in industrial companies to collect and store asset-related data (Kortelainen et al. 2021). Asset-related data is contained in various information systems such as enterprise resource management (ERP) or computerized maintenance management systems (CMMS). Information systems are typically used for operational-level decisions (creating maintenance work orders, for example). However, maintenance history data is also valuable when making asset management-level decisions, such as investment decisions. Therefore, while a considerable amount of data is stored, tacit knowledge is necessary for conscious decisions (Kortelainen et al. 2015). In other words, people's competence and experience play a crucial role in decision-making (Kortelainen et al. 2021). In the same way that tacit knowledge is necessary for decisions, the research by Mahlamäki and Nieminen (2019) aimed to identify factors that affect the CMMS use by maintenance technicians in the manual collection of asset data. As a result, the study reveals that technicians who collect good quality data have received suitable training and instruction for the CMMS, are competent, and understand how manually collected data benefits them in their work.

The term Industry 4.0 appeared in 2011, and since then, it has been used to describe the broad integration of information and communication technology in manufacturing companies (Schuh et al. 2020). Suppose that half of the large global companies use some technological innovations to maintain their equipment in the next five or six years. In that case, it can be said that they will positively disturb people, business objectives, information systems, and asset performance Industry 4.0 is expected to bring about substantial changes in how maintenance and AM will be conducted in the coming years. Three areas of technological innovation related to Industry 4.0 will affect maintenance and asset management: intelligent maintenance, intelligent work, and intelligent products (Pedersen and Schjølberg 2020). With the fourth industrial revolution, the maintenance function in a company is forming itself into intelligent maintenance. With the help of artificial intelligence, it is considered that maintenance planning will provide better and faster decision-making in maintenance and AM (Rødseth et al. 2020). The design of Industry 4.0 highly demands the integration of all development, manufacturing, logistics, and maintenance processes. In this area, there is much to improve and implement. The corrective maintenance system still prevails, but the pressure on predictive and proactive maintenance will continue to grow (Pavlu et al. 2019).

Risk quantification analysis is one of the most critical areas in asset management, as established in ISO 55000. Likewise, intelligent risk management must be a crucial challenge in Industry 4.0. With new technologies, it will be possible to gather large amounts of data extrapolated from physical assets (González-Prida et al. 2020). Artificial Intelligence (AI) can improve risk mitigation by analyzing these large amounts of extrapolated data, continuously identifying evolving patterns, and predicting events, together with possible solutions (Walter 2019).

Investments in digital technologies provide managers with quick solutions and high-quality information to improve decision-making, highlight performance trends, and reduce costs. However, it ignores that managers have biases and, regardless of how accurate or reliable the data is, they may not use it effectively or even choose to discard the information. Therefore, organizations must put users who will create meaning from information at the center of their digitization initiatives. In addition, organizations need to challenge how employees will use data to make decisions and, at the same time, encourage them to rely on formal analysis rather than just their "intuition" (Love and Matthews 2019). Thus, the term Industry 4.0 is not just a technological transformation. Companies also need to transform their culture. Advanced technologies enable access to a wide range of data; however, implementing these technologies and harnessing the data's underlying potential depends on the organizational structure and corporate culture. The ultimate goal is to become a company that learns agilely and adapts continuously in an ever-changing environment (Schuh et al. 2020).

Cultural/behavioral change and knowledge management are necessary conditions for the faster progress of all other innovations; technical and process innovations are good and very important, but without putting people first, they will all fail (Akkermans et al. 2016).It is increasingly evident that companies with successful digital strategies share very similar characteristics: they all have cultural mentalities closely related to digitally matured companies; they value experimentation and speed, embrace risk, and create distributed leadership structures to promote collaboration and be more likely to use data in decisions (Akkermans et al. 2016; Kane et al. 2016). These are the 'smart moves' that all organizations will have to take on their path to maturity in smart maintenance (Akkermans et al. 2016).

Competing in an increasingly digital world is not just about implementing more and better technologies. It involves aligning the organization with the demands of the digital environment, increasing the risk appetite, investing in digital opportunities for its employees, simplifying organizational structures to gain agility, and rethinking how and by whom the work is done. Only when these organizational factors come together can a company change from "making digital" to "being digital"(Kane et al. 2016). Digital transformation is one of the main reasons to survive in the era of Industry 4.0, which helps organizations to become competitive and, simultaneously, allows them to make ideal decisions in all phases of their activities (Venkateswaran 2020). However, in light of the impetus to implement digital technologies, organizations, before making financial investments, need to validate a process of all benefits to understand "how" these technologies can be used and thus, they can generate business value and improve competitiveness (Love and Matthews 2019).

3. Methods

The methodology used was a literature review. This study was carried out research on books, dissertations, and scientific articles available in electronic journals - through search sites such as Scopus, Scielo, Google Scholar, websites of associations and asset management organizations, asset management congresses books, practical manuals, and others, of the period from 2010 to 2022. The search used the following descriptors: asset management, physical asset management, asset data, asset information, information management, ISO 55001, and Industry 4.0.

4. Results

Most manufacturing companies have difficulty properly managing their equipment due to the lack of quality information. For example, the data are disconnected because several departments and people are recording them. Moreover, it is probably not precisely known what equipment the data represent. Thus, the companies have difficulty managing their physical equipment, whose assets support them. So, how to improve the information management of production equipment in a manufacturing company? The first objective can be establishing a registration and data collection standardization to improve asset information management through the ISO 55001 requirement, even if the company does not want to be certified with the standard.

This work suggests that compiling quality data with proper training is possible. Furthermore, it is possible to obtain quality information by distributing the collecting of data to each asset responsible operator and then integrating all data into the ERP (or another available system). Thus, managers can obtain quality information. Finally, recommendations on the quality of data collection were made based on the study by Ho et al. (2014) about how to avoid erroneous data in the ERP through actions to mitigate or eliminate the causative problems:

- Develop standardized vocabulary and notes for each action;
- Standard terms should be used for the same subsystem, maintenance item, and component;
- The actions and the ERP must be in the language of the operators and maintainers who generate;
- Work Order (WO) and reflect what is observed (instead of the failures that the engineers think might happen);
- There must be a separate field in the ERP to indicate a suspension - it occurs when a maintenance item is removed, but it still works. The data is vital to determine the equipment reliability since accounting for breaks can lead to gross errors in estimating statistical parameters such as the mean time between failures (MTBF);
- Create separate work orders for each subsystem, maintainable item, or changed component. Components that are changed together need to be registered separately. Hence, it is easy to see when each component was changed;
- Carry out a review that allows accounting for the difference between a significant rebuild, work resulting from maintenance tactics (replacements at fixed intervals of life, condition monitoring, inspections), and jobs generated by operators and maintainers who are not part of a maintenance tactic;
- Although it is not directly required for the reliability analysis, a correct value in the cost field and access to data on labor costs and downtime can be considered. It helps deduct the WO action (inspection, minor repair, major repair, change out) or the number of parts changed out if this information was not given;
- One should consider creating reports based on data from maintenance plans, spare parts, maintenance contracts, and equipment use hours to obtain a complete image of the asset.

How the asset inventory is one of the most critical components of the Asset Management System, this research also suggests that the asset portfolio inventory is in the ERP (or another system) to ensure synchronism, updating, reliability, quality, and traceability of information.

Table 1 shows how the information can be separated between groups.

Table 1. Asset information groups

• Asset Identification • Financial Information • Use • Performance • Criticality • Risks And Contingency Plans • Specific Competence Requirements

Table 2 presents which identificationsthe asset can have.

Table 2. Asset identifications

• Asset ID (Identity) • Tag with Number Patrimony • Location • Type of Asset • Function, Manufacturer • Year of Manufacture • Date of Acquisition • Entry into Service.

Table 3 exhibits whatthe financial information can be.

Table 3. Financial information

▪ Acquisition Costs ▪ Operating Costs ▪ Maintenance Costs ▪ Expected Useful Life ▪ Depreciation ▪ Residual Value ▪ Replacement Costs (when possible)

Table 4 demonstrates the meanings of utilization, performance, and risks.

Table 4. What utilization, performance, critically, and risks mean

❖ **Utilization** is about a relation between the production hours and the available hours ❖ **Performance** is about reliability, availability, and cost indicators ❖ **Criticality** is the importance of the asset to the intended results ❖ **Risks** are the potential impacts of the failure of this asset (the probability of the event versus the effect of the consequence) and the contingency plans for that asset, that is, which equipment can replace it so that there is no interruption in production

Concerning the specific competence requirements of the assets, the companies should ensure that operators have the knowledge, understanding, skills, and experiences necessary to safely perform their function, meet operational

objectives, and avoid related failures to human error. These suggestions can be the first step for companies looking to manage information on their assets. Without it, no company is prepared to use the benefits provided by Industry 4.0 equipment.

5. Conclusion

With information management, companies can migrate from a reactive stage to a preventive stage; their data can be transformed into information and considered extremely valuable for future actions. If the information is used correctly, decisions in managing its assets will be safer and more effective. Data from this research also suggest how possible access to information will be with introducing intelligent equipment. However, most companies are unprepared for this disruption, even with technology that allows for real-time information. Just as successfully implementing the ISO 55001 requirements is linked to corporate culture, acquiring new technologies and using their data depends on organizational factors, such as cultural/behavioral change and knowledge management. Thus, to make effective decisions, the companies must continue investing in their best asset: people.

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Biographies

Ana Carolina Gandini Panegossi, Master, was born in Matão SP, Brazil, on April 11, 1979. She holds a degree in Industrial Engineering - Chemistry - from the Federal University of São Carlos (UFSCar), a specialist in Ethanol Quality from the Federal Institute of São Paulo (IFSP), campus Matão; a Master's Degree in Industrial Engineering from the University of Araraquara (UNIARA). She is also a Doctoral student in the Regional Development and Environment Program at the same institution since 2022. She has been working on research involving asset management and equipment replacement and has been published and presented her research at congresses. She is also an ABRAMAN (Brazilian Maintenance and Asset Management Association) associate and a member of ABNT/CEE-251 - Special Study Commission on Asset Management of the Brazilian Association of Technical Standards.

Ethel Cristina Chiari da Silva, Ph.D., was born in São Carlos, SP, Brazil, on February 27, 1966. She graduated in Industrial Engineering - Materials - from the Federal University of São Carlos (UFSCar) in 1990; she got a Master's Degree in Mechanical Engineering (research area: Industrial Engineering) from the University of São Paulo (USP) in 1994. She obtained her Ph.D. in Mechanical Engineering (research area: Industrial Engineering) at the same institution in 1999. She coordinates the undergraduate course in Industrial Engineering at the University of Araraquara (UNIARA) and teaches in the Professional Master's Program in Industrial Engineering at the same institution. In addition, she has been working on research involving lean manufacturing and operations management.

Marcus Cesar Avezum Alves de Castro. Ph.D. Degree in Mechanical Engineering (EESC-USP). Master's and Doctorate in Hydraulics and Sanitation from the University of Sao Paulo. Solid Waste Professor at the Sao Paulo State University, Rio Claro (UNESP). Adjunct Professor of the Environmental Engineering course at the same institution. Master and Doctoral Professor in the Post-Graduate Program in Territorial Development and Environment at the University of Araraquara. Areas of expertise: management, treatment, and final disposal of solid waste. Generation of energy from solid waste.