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A ANALYSIS OF THE POSSIBILITY OF REDUCING SPARE PARTS IN THE MAINTENANCE CONTEXT 4.0

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ABSTRACT

Equipment inspection arose from the need to maintain industrial facilities in satisfactory physical condition, providing the minimum level of safety and reliability in operation and maintenance. Machines and equipment cannot stop operating without planning and managing the supply chain, maintaining large quantities of spare parts stocks. The objective of this work is to analyze the possibility of predictive and / or prescriptive monitoring to contribute to the preventive maintenance of the real condition of the equipment, that is, only in real need, avoiding preventive maintenance for pre-established intervals, consequently reducing the stock of spare parts. To this end, a Systematic Literature Review (RSL) was carried out using the keywords Maintenance 4.0 and Supply Chain Management and Industrial Logistics, identifying the main authors and most relevant journals.

Keywords: Maintenance 4.0, supply chain management, Industrial logistics

1. INTRODUCTION

The concept of Industry 4.0 aggregates the main technological innovations from various segments and applies them in the manufacturing and service processes. These are technologies that have allowed the emergence of new business models, products and services, and have fostered significant improvements in existing models.

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For Schwab (2016), new technologies are transforming the way organizations perceive and manage their assets, receiving improvements from digital resources that increase the values of both products and services. The challenge with these new technologies is to guarantee the operational reliability of automated equipment, enabling the operational condition in real time, identifying and acting on the potential point of failure, while notifying the situation, through the internet of things (IoT) for a mobile device under the responsibility of Maintenance Planning and Control (PCM).

A análise fornecida por sensores *off-line*, *on-line* ou contínuo, colocados nos equipamentos permitem constante monitoramento preditivo e/ou prescritivo, buscando o ponto potencial de falha, usando os dados comparativos sobre o desempenho, que podem notificar quando uma parte do equipamento está fora de seus parâmetros normais de operação.

The analysis provided by offline, online or continuous sensors placed on the equipment allows constant predictive and / or prescriptive monitoring, looking for the potential point of failure, using comparative performance data, which can notify when a piece of equipment is outside its normal operating parameters.

After the notification, preventive maintenance of the actual condition of the equipment will be programmed, making it possible to forecast the part, only those or the one that was identified in the monitoring, providing a reduction of a good part of the spare parts stock, in this way purchases will be made only according to with the need

The objective of this work is to analyze the possibility of predictive and / or prescriptive monitoring to contribute to the preventive maintenance of the real condition of the equipment, that is, only in real need, avoiding preventive maintenance for pre-established intervals, consequently reducing the stock of spare parts.

For this purpose, a Systematic Literature Review (SLR) was carried out using the keywords Maintenance 4.0 and Supply Chain Management and Industrial Logistics, identifying the main authors and most relevant journals.

The article is structured as follows: section 2 presents the Theoretical Foundation related to Industry 4.0, Supply Chain Management and Industrial Logistics and the correlation between these concepts, Section 3 shows the Research Method pointed to the study, the Section 4 presents the Results, Section 5 presents the Analysis and Discussion of

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the selected articles, Section 6 the Findings and Trends and Section 7 provides the main conclusions on the Theme

2. THEORETICAL FOUNDATION

This section presents a review of the concepts of Industry 4.0 and Supply Chain Management and Industrial Logistics and their links

2.1. Industry 4.0

With increasing advances in manufacturing processes and technology, the term "Industry 4.0" is becoming an increasingly important topic. This concept appeared first in an article published in November 2011 by the German government that resulted from a relative initiative to the high-tech strategy for 2020.

Schwab (2016) comments that in Germany, there are discussions about Industry 4.0, a 2011 term at the Hannover fair to describe how this will revolutionize the organization of global value chains. By enabling smart factories, the fourth industrial revolution creates a world where physical and virtual manufacturing systems cooperate globally and flexibly, allowing for complete product customization and the creation of new operational models.

Odważny et al. (2019) comment that within this period, several models and ideas were developed, in particular smart factory, Internet of Things (IoT), Internet of Services (IoS), cloud computing and cyber-physical systems (CPS), complemented by Robotics, Big Data, Cloud Manufacturing and Augmented Reality (Pereira & Romero, 2017).

2.2. Supply Chain Management

For Mastos et al. (2020) the fourth industrial revolution and the digitalization of supply chains led companies to realize that the adoption of Industry 4.0 / IoT solutions creates opportunities for management. In the past decade, significant growth in Sustainable Supply Chain Management (SSCM) and Industry 4.0 research has been observed. The definition of SSCM given by Seuring and Muller (2008) is: “Management of materials, information and capital flows, as well as cooperation between companies in the supply chain, making goals of all three dimensions of sustainable development (Environmental, Social and Economic), which are derived from the requirements of customers and stakeholders ”.

For more sustainable production processes and information sharing at SSCM, simulation and forecasting techniques are used to address the needs of supply chains such as:

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flexibility, increased productivity, less waste, optimization of a plant's internal and external resources, through big data analysis, IoT and learning techniques.

2.3. Industrial Logistics

Tang and Veelenturf (2019) comment that the logistics function deals with the detailed coordination of a complex operation involving human resources, materials, equipment, information and finance and, in many cases, this coordination involves the movements of materials, human resources and / or equipment, or exchanges of information between human resources and / or devices, and financial transactions between entities.

The preventive maintenance of the equipment's real condition, will enable the department to buy, acquire materials / parts only when necessary for use, and not stock of spare parts.

2.4. Industry 4.0, Supply Chain Management and Industrial Logistics

Industry 4.0, Supply Chain Management and Industrial Logistics are interconnected through connectivity in the context of Industry 4.0 and manufacturing companies identify opportunities to develop their competitiveness in their operations and organizational efficiencies.

For Benesova et al. (2020) changes in Industry 4.0 will have an impact on the organization on the company's architecture and on the production environment and on the Supply Chain. Glawar et al. (2016) comment that without correct machine data it is difficult to plan a good maintenance activity. Therefore, with real data it will be possible to improve Maintenance Planning and Control (PCM), allowing purchases to be made only in real need, avoiding spare parts stocks.

3. RESEARCH METHOD

The research method adopted to achieve the objective of this work was based on an RSL that is a scientific process, allowing the evaluation of the literature, through the identification of the selection and the evaluation of the existing studies (Tranfield, Denyer & Esmart, 2003)

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3.1. SLR Protocol

This SLR was carried out through the Software Start - State of the Through Systematic Review, version 3.4 Beta - LAPES - Laboratory of Research in Software Engineering - UFSCAR.

The research protocol is shown in Table 1:

Table 1: Research Protocol

Strategy	**Protocol**
Research question	Será possível reduzir peças sobressalentes no contexto da indústria 4.0
Data base	Scopus, Web of Science, Science Direct
Key words	"*Maintenance 4.0*" And "*supply chain management*" "*Maintenance 4.0*" And "*Industrial logistics*"
Period	2015 a Setembro/2020
Language	Inglês, Português, Espanhol
Exclusion criteria	• Titles unrelated to the research objective. • Duplicate articles. • Do not contain search strings in the title, abstract and keywords. • Articles published outside the period. • Books, Sites and Theses
Inclusion criteria	• Articles that contain the title, abstract and keywords in the search strings. • Articles published in the period

Source: Authors

3.2. Initial Research and Refinements

The initial research resulted in a total of 37 works, in the period from 2015 to September / 2020, as shown in Figure 1 by database.

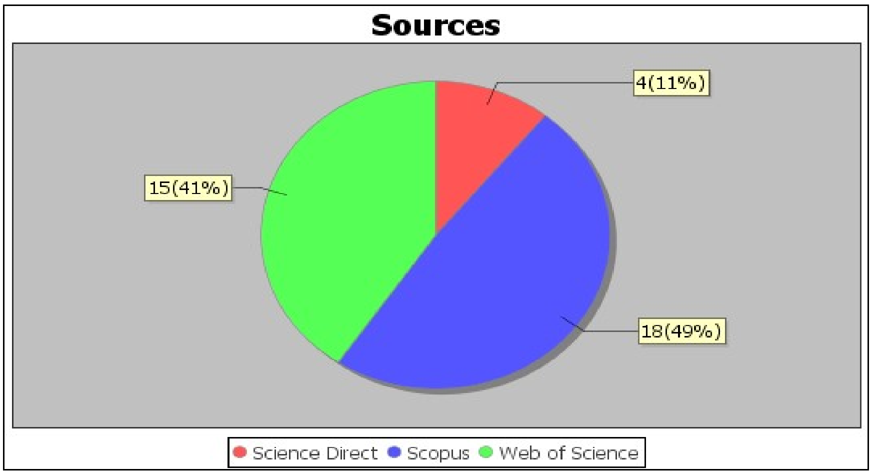

Figure 1: Initial result by database
Source: Start

Three initial results filtering processes were carried out to select the articles to be evaluated:

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- First filter: Exclusion of titles not related to the research objective, duplicate articles, articles that do not contain in the title, abstract and keywords the search strings, articles published for the period, books, websites and theses, resulting in 19 articles rejected and 6 duplicate articles, distributed by year of publication, shown in Table 1.
- Second filter: Inclusion of articles that contain the search strings in the title, abstract and keywords, articles published from 2015 to September / 2020, with English, Portuguese, Spanish languages, resulting in 12 articles distributed per year of publication, as shown in Table 1.

Table 1: Result of exclusion

Articles	2015	2016	2017	2018	2019	2020	Total
Accepted	0	0	0	3	1	8	**12**
Rejected	0	0	3	5	3	8	**19**
Duplicates	0	0	0	0	1	5	**6**
Total	**0**	**0**	**3**	**8**	**5**	**21**	**37**

Source: Authors

- Third filter: It consisted of reading the abstracts and conclusions of these 12 articles, in order to select only those articles that address the research objective, resulting in 9 articles for analysis, shown in Table 2.

4. RESULTS

Analyzes of the data of the 9 selected articles will be presented, by year of publication, by periodicals, and by citations.

Table 2 shows the total number of articles selected and published per year, and the first articles observed were in the year 2018, in addition, the year 2020 presented the largest number of publications on this topic. From the year 2018, the first published in the MM Science Journal, by Pelantova, Cecak (2018) of the Faculty of Mechanical Engineering, KSA - Czech Republic, whose focus of the article is the list of spare parts materials and the origin of non- conformities of a production, these facts being seen as meaningful and contextualized.

Table 2: Articles selected and published by year

Articles	2015	2016	2017	2018	2019	2020	Total
Accepted	0	0	0	1	1	7	**9**
Rejected	0	0	0	2	0	1	**3**
Total	**0**	**0**	**0**	**3**	**1**	**8**	**12**

Source: Authors

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Table 3 shows the journal that most published on the topic: Sustainability with 2 of the 9 selected articles.

Table 3: Journals with numbers of publications

Journals	Numbers of publications
Acta Logística	01
Eksploatacja I Niezawodnosc	01
IEE Acces	01
International Journal of Mathematical Enginnering and Management Scices	01
International Journal of Production Economic	01
MM Science Journal	01
Sustainability	02
Tehnicki Glasnik	01
Total	**09**

Source: Authors

The analysis of citations shows the number of times the work has been cited over time, with the articles with the highest number of citations being presented in Table 4, identifying a total of 13 authors in the four most cited articles (Top Four).

The article with the highest number of citations is that of Bokrantz et al. (2020) with 13 citations. This article dealt with the relevance of how modernized maintenance operations, often called “smart maintenance”, affect the performance of factories, followed by HoffaDabrowska and Grzybowska (2020) with 06 citations, addressing in the article that aspects of SSCM have become increasingly popular in recent years, not only in economic, but also environmental and social aspects.

Table 4: Most cited articles (Top Four)

Author / Year	Articles	Numbers of publications
Bokrantz, J. Skoogh, A. Berlin, C. Wuest, T. Stahre, J. (2020)	Smart Maintenance: an empirically grounded conceptualization	**13**
Hoffa-Dabrowska, P.; Grzybowska, K. (2020)	Simulation modeling of the sustainable supply chain	**06**
Granillo-Macias, R., Simon-Marmolejo, I., Gonzalez-Hernandez, I. J. Zuno-Silva, J. (2020)	Traceability in industry 4.0: A case study in the metal-mechanical sector	**06**
Pelantova, V., Cecak, P. (2018)	New aspects of maintenance management and the material of spare parts	**05**

Source: Authors

5. ANALYSIS AND DISCUSSION

The selection of Small and Medium Enterprises (SMEs) is encouraged by the fact that SMEs with growth speed in the global economy, lack knowledge about Industry 4.0. They are characterized by limited resources (skilled workers, infrastructure and budget), and for

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European commission they are companies that employ less than 250 workers and have a turnover of up to $ 50 million / year, while in Germany they are defined as companies that it has less than 500 employees, however, flexibility in decision making is relatively easier and faster compared to large companies, due to the short bureaucratic path and few people (Harmoko, 2020).

The author also comments that benefits of Industry 4.0, was initiated by a group of academic entrepreneurs and collective German strategy of companies that equip their business processes, especially the production process with Digitization, IoT, CPS and intelligent factory, presenting the synchronization in real time of business and production flows and their application has three main objectives: i) to reduce time to market; ii) increase flexibility; and iii) increase efficiency. With the fulfillment of these goals, the benefits of Industry 4.0 can be felt by the company and the national economy. In Germany, the adoption of Industry 4.0 increased the company's efficiency by 25% and contributed about 1% per year to the Gross Domestic Product (GDP) in 10 years, in addition to creating 390,000 jobs volume_up.

Valamede and Akkari (2020) comment that the benefits of industry 4.0 relating to interconnectivity and data analysis, human-machine association and employee training, support and enable the planning and activities of the maintenance operation in a digital environment. Smart factories will provide a fully integrated manufacturing environment, where data can be transmitted in real time, making it possible to indicate the real conditions of each equipment, and for Proto (2020) the emergence of factories in Industry 4.0, fostered the diffusion of IoT technology and great data analysis tools in the industrial sector, called logistics 4.0, profoundly increasing the needs for transparency in the supply chain and integrity control in good sales and delivery (selling the right product, at the right cost and delivering it them at the right time and place).

According to Ales et al. (2019) the challenge of Industry 4.0 with the issue of Industrial Internet of Things (IIoT) is highly accentuated, including the issue of autonomous management and communication of individual machines and equipment within a higher production and complex units.

According to Bokrantz et al. (2020) the world is changing rapidly, indicating surprising technological developments and one of the most impactful technologies driving this change is Artificial intelligence (AI) and Machine learning (ML) with more accessible

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technologies, such as cloud for storage and computing power, stimulating companies to adopt new organizational forms such as networks, ecosystems, platforms and collaborative communities.

An important aspect of manufacturing companies that requires design efforts is the plant maintenance function, due to exploring the improvement of technological capacity such as ML, with the increasing automation and introduction of digital technologies in production systems, with expected benefits of drastic reduction machine downtime and increased productivity. It is possible to advance in the understanding of what makes certain practices effective, however the number of concepts grows, so does the concern with problems due to the lack of clarity of the concept, manifesting in the proliferation of concepts with different names. "E-maintenance", "Prognostics and health management", "Predictive maintenance", "Maintenance 4.0", Intelligent maintenance ".

Still Bokrantz et al. (2020) comment in practice, "intelligent maintenance" is the term used by professionals in local companies within the Swedish manufacturing industry, which is also observed in other countries. According to the author, the lack of consensus regarding a definition of E-maintenance, motivated the work of Iung et al. (2009) and Aboelmaged (2015) who has reviewed 15 definitions of electronic sample maintenance in publications over an 11-year period and concludes that “there is little room for clarification and confusion in the literature as to what constitutes an E-maintenance definition”, with some explanations for this, inconsistency as a country with European and American location and technological changes from Information and communication technology (ICT) to AI.

For Hoffa-Dabrowska and Crzybowska (2020) aspects of SSCM have become increasingly popular in recent years and entrepreneurs pay more attention to the aspect of sustainable development in their activities, especially in exhaust gas emissions. Supply Chain Management (SCM) has developed into an important conceptual approach within the management and administration of companies.

For Pelantova and Cecak (2018) the guarantee of continuity and quality of production leads some organizations to think about the status of the maintenance of their equipment and also depend on the spare parts. Maintenance is influenced by many factors at the moment, and must present new guidelines for maintenance management, where the list of spare parts materials and the origin of non-conformities in a production plays an important role, seeking to reduce costs in organizations

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With the emergence of production systems characterized by Industry 4.0 technologies, the problems of asset traceability have become more relevant at different levels of the supply chain. The management of intelligent assets promoted by Industry 4.0 is considered as a process that, in addition to collecting information, allows to track and guarantee the security of assets (Granillo-Macias, 2020).

Di Nardo et al. (2020) comment that the logistic workflow is oriented towards Industry 4.0, with technologies capable of identifying suppliers' performance indicators and implementing them in the supply chain process. Currently, a customer is drafting a contract in which cost, quality and availability control are included and the supply of material takes approximately 5 to 45 days through the full service approach, ensuring high levels of availability and reliability in an intelligent environment. Industry 4.0, and also comment that the components of machinery and equipment age progressively, being the main cause of wear in the form of material degradation, with a tendency to change the parameter during the useful life of an item.

With the monitoring of machines it is possible to foresee the need for a maintenance intervention, making the predictive monitoring strategy viable, and the maintenance activities will be planned based on the real operating conditions. With this dynamic of the digital model in maintenance, or Maintenance 4.0, it is possible to identify the status of components and parts in real time of the machines, through analysis of the sensor data, showing the signs of failures.

Predictive maintenance has a double objective, according to Proto (2020): i) to reduce the frequency of maintenance activity to the lowest possible state, leading to enormous cost savings in keeping resources under normal working conditions; ii) avoid catastrophic situations (product failures and failures, service interruptions) detecting anomalies a priori of historical data and maintenance activity must be carried out in time to prevent the occurrence of failure.

6. FINDINGS AND TRENDS

According to Harmoko (2020) for small and medium-sized companies, the lack of knowledge about Industry 4.0 is characterized by limited resources (skilled workers, infrastructure and budget), making it difficult to significantly improve their processes. The benefits of industry 4.0 relating interconnectivity, data analysis, human-machine association

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and employee training, Valamede and Akkari (2020) comment that they support and enable the planning and activities of the maintenance operation in a digital environment.

For Proto (2020) the emergence of factories in Industry 4.0, fostered the diffusion of IoT technology and great data analysis tools in the industrial sector, called logistics 4.0, profoundly increasing the needs for transparency in the supply chain and integrity control good sales and delivery (selling the right product, at the right cost and delivering it to the right place at the right time).

Bokrantz et al. (2020) comment that the number of maintenance concepts grows, worrying about the lack of clarity of the concept, manifesting in the proliferation of concepts with different names

For Pelantova and Cecak (2018), the guarantee of continuity and quality of production leads some organizations to think about the maintenance status of their equipment that depends on spare parts, because spare parts in a long supply chain mean an expensive price and longer delivery time.

According to Di Nardo et al. (2020) the logistical workflow is oriented towards Industry 4.0, with technologies capable of identifying supplier performance indicators and implementing them in the supply chain process, and for Granillo-Macias (2020) the problems of traceability of assets become more relevant at different levels of the supply chain.

And yet Di Nardo et al. (2020) highlight that with machine monitoring it is possible to predict the need for a maintenance intervention, making the predictive monitoring strategy viable, and the maintenance activities will be planned based on the real operating conditions

Predictive maintenance has a double objective, according to Proto (2020): i) to reduce the frequency of maintenance activity to the lowest possible state, leading to enormous cost savings in keeping resources under normal working conditions: ii) avoid catastrophic situations (product failures and failures, service interruptions) detecting anomalies a priori of historical data and maintenance activity must be carried out in time to prevent the occurrence of failure.

7. CONCLUSÃO

The objective of this work was to analyze the possibility of predictive and / or prescriptive monitoring to contribute to the preventive maintenance of the real condition of

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the equipment, that is, only in real need, avoiding preventive maintenance for pre-established intervals, consequently reducing the stock of parts spare parts, identifying a total of 9 articles analyzed

The systematic review contributed to verify the current situation of the literature in relation to the maintenance approach in the Industry 4.0 environment, in addition to pointing out the most relevant works for analysis and understanding of the subject.

The analyzed studies showed that Maintenance 4.0, through predictive and / or prescriptive monitoring with sensors placed on machines and equipment, contributes to the identification of the potential point of failure, providing preventive maintenance activity of the real condition of the equipment, that is, carry out only in real need, avoiding a stop for preventive maintenance for a pre-established time, allowing a reduction of a good part of the stock of spare parts, and purchases will be made according to the need.

With the application of technology, the preventive maintenance of real condition, that is, in real time of the measurement sensors, contributes to the improvement of the economic performance of the manufacturing processes and provides process stability. Connected technologies can help Maintenance Management and Supply Chain Management, with the challenge of having the right part, in the right place and at the right time.

The review carried out has the following limitations: few studies were selected with the theme analyzed, the selection and filtering criteria were based on the keywords, which may have led to the non-inclusion of some articles relevant to the study, due to not combining the keywords.

As suggestions for future research: use the combination of keywords, as well as better definition of the concepts of Maintenance 4.0, proposing a performance indicator for this concept.

Despite the limitations presented, the article contributes to the literature, with the scope of action that the theme allows.

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