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Labor Skills in the Maintenance Department for Industry 4.0

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By

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Industry 4.0 is changing the manufacturing environment with its cyber-physical infrastructure to support and help increase production performance. The cyber-physical infrastructure brings new technologies such as Internet of Things, big data, cloud computing, and machine learning using advanced algorithms. To deal with this new order to preserve asset performance, industrial maintenance needs to be prepared. This study aims to understand the impact of Industry 4.0 on the skills required within industrial maintenance departments. A survey of industrial maintenance professionals finds that the majority of training comes from internal sources and that much of the information systems used for training are out-of-date or does not exist. The results of this study show that Industry 4.0 will impact the maintenance department and that a Change Management process should be put in place to accomplish this transition smoothly.

DEDICATION

To my domestic partner Scott Speser who always has been supporting of this journey and gave up many weekends without leaving home when I needed to study. His words of encouragement helped me during difficult times when I thought that I might quit.

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CHAPTER I

INTRODUCTION

Maintenance has the challenge of preserving equipment life at the right cost, offering a high level of availability and avoiding unexpected breakdowns due to problems caused by missing scheduled preventive maintenance. As equipment is evolving to the Industry 4.0 platform, new technologies are embedded in this equipment. This equipment may be able to self-adjust using self-learning algorithms, have measuring sensors that are connected to transmitters, and/or use the Internet of things (IoT) to continuously transmit data to certain databases located in the cloud. Software, computer networks, sensors, signal interpretation, conversion platforms, data transmissions, and IoT are no longer only for the information technology (IT) department; it is present in Industry 4.0. This work aims to understand the role of the individual in maintenance in Industry 4.0.

Background

Companies realized out there is a way to add value to production activities through developing a strategy to maintain systems and equipment (Nikolopoulos, Metaxiotis, Lekatis, & Assimakopoulos, 2003). To perform this activity, maintenance has basically two resources available: tools and people. They are intertwined with knowledge as the driving force of these two resources. People create the tools for a need, and the tools achieve a result that people could not reach alone, and another need is generated from the expected result. Thus, the evolution of both follows.

Parallel to human evolution and its tools, the evolution of machines is present in industrial revolutions. Starting with factories that were steam powered, industry was born. The introduction of electric power changed the panorama of industry, as it was installed in more and more companies. The discovery and improvement of electronics marked the entry of the 3.0 age of industry (Bassi, 2017) (Rü\s smann et al., 2015). These evolutions are identified as the change of processes to manufacture the same product, the evolution of machinery to increase the rate of productivity, and the improvement of equipment that increases quality levels.

The technological evolution of factories brings the challenge of maintaining the equipment contained therein. The addition of and challenges presented by IoT devices, communication platforms, cyber security, and others (Ghionea, Ghionea, Cioboată, & Ćuković, 2016) didn't exist in Industry 3.0. The issues generated by these components can be considered as new challenges. Cyber security is another issue raised by Rü\s smann et al., (2015) since production systems are now connected to a network or internet which increases the risk on malicious intrusions from cyberspace.

The knowledge gained from the previous technology can help in the process, but it is not enough. In addition to the small evolutions that take place through the years, the greatest changes take place in decades (Siebenhüner, Arnold, Eisenack, & Jacob, 2013). The latest industrial revolution is said to have started in 2011 (Henning, 2013), and it is still in process, migrating from electronics driven and proprietary software to a digital platform with open source software and with the Internet at the center of this evolution. This is known as Industry 4.0, which the German Government defines as the challenge to integrate technologies such as Cyber-Physical Systems, Internet of Services, and Internet

of Things (Ghionea et al., 2016) (Henning, 2013). Industry 4.0 is composed by several technologies related to Cyber-Physical Systems, Internet of Things, Internet of Services and Data Mining (Li, Wang, & He, 2016).

According to Fleischmann, Kohl, & Franke (2016) people are the success factor for Industry 4.0 and act as the main factor in socio-cyber physical systems (Socio-CPS). Maintenance professionals are even more important because of their work to maintain production resources and ensure availability. The same professionals who maintained equipment commanded by PLC now needs to maintain equipment commanded by non-proprietary software, connected to the Internet, generating a great amount of information on the parameters of production (Spendla, Kebisek, Tanuska, & Hrcka, 2017).

The traditional role of the maintenance department is the maintenance of physical assets and facilities. Now, driven by Industry 4.0, maintenance will also maintain the logical part of this equipment. A problem presented by equipment may have been caused by a program codification failure within the software. As previously mentioned software in Industry 4.0, tends not to be proprietary. In this case proprietary means that only the vendor has access to the software to make corrections and improvements at the level of program code; non-proprietary code troubleshooting will fall upon the user. The IoT platform for interpreting, transforming, and transmitting data and the cloud-based manufacturing performance analysis platform are some of the new assets that are embedded in manufacturing (Lesjak, Ruprechter, Bock, Haid, & Brenner, 2014; Papakostas, O'Connor, & Byrne, 2016). These platforms need to be maintained and determined by maintenance techniques or policies.

Rü\s smann et al., (2015) sets as a priority for producers to adapt actual roles, recruiting, and vocational training to prepare the workforce with IT skills. Transposing this priority to the world of maintenance, there is a need for the maintenance professional to know how to keep this new complex system installed where IT is fully integrated into manufacturing, then the professionals who have knowledge of this technology are still working in the IT department. They are system analysts who work to keep the back office running and do not know the manufacturing processes, the equipment, and the nuances of maintenance of the equipment. Thus, there is likely a knowledge gap that needs to be filled and managed.

Scientists have been researching and fostering knowledge in Industry 4.0 since 2011 (Henning, 2013). Education needs to be adapted to offer IT skills, changing school curricula, and University programs (Rü\s smann et al., 2015). Universities, ("ISE Courses | Industrial & Systems Engineering :: Mississippi State University :: Bagley College of Engineering ISE Courses |," n.d.), industries (*Industry 4.0 and Change - Festo Training and Consulting*, 2017) and institutes (PM.ORG, 2018) have started teaching classes regarding industry 4.0 technologies such as concepts, protocols, application, and in the academic environment: Heuristics in Optimization, Systems Simulation, and others (Richards, 2018).

Professional Significance

The maintenance department is not at the forefront of a manufacturing system. The best investments, the highest priorities, and the best infrastructure almost always belong to other departments (Swanson, 1997). Based on this premise, studies for this department are not on the same level as other departments.

This study intends to fill a knowledge gap regarding the maintenance department in Industry 4.0. The study will help industries, practitioners, and scientists complement each other's knowledge by demonstrating how the workforce pertaining to the maintenance department will absorb the knowledge needed to meet the industry's challenges.

Regarding the management of the maintenance department, this study will help the current managers prepare the new structure that the department should have due to the technological changes introduced by Industry 4.0.

Problem Statement

Although the maintenance professional already has experience and knowledge to deliver quality service at a reasonable cost and offer a safe environment to ensure high levels of equipment availability, recent developments such as IoT, communication platforms, cloud computing, machine learning, etc, in Industry 4.0 require a complement to the knowledge already acquired and require new organization enterprises to align the new technologies implemented by Industry 4.0.

CHAPTER II

LITERATURE REVIEW

A coordination of activities including planning, scheduling, executing, and analyzing, in which the value added to assets defines asset management. Value can be described as costs, risks, opportunities, and improvements (ISO 55000: 2014, 2014). The ISO 55000:2014 standard can be applied to any kind of asset. Horner, El- Haram, and Munns (1997) described it as building maintenance goals, including safe conditions for related buildings and services, availability for use, meeting regulations, working to maintain physical assets, and maintaining the quality of buildings. Companies that apply asset management understand the combination of throughput and that costs and reliability provide a financial return (Katicic & Lovrincevic, 2012).

The biggest effect that the maintenance department can make is the availability of the equipment for production. Without available equipment, products or services cannot be delivered, and the production rate decreases as the equipment becomes unavailable for use. The availability of equipment in percent is given by the formula:

$$a = \frac{available\ time\ to\ produce}{total\ time\ planned} \quad (1)$$

The total planned downtime is considered the downtime to set up and perform planned equipment adjustments, while downtime due to failures is considered unplanned time (Wolff & Schmitz, 2017).

Rather than contributing to the increased availability of equipment, the maintenance department can contribute to reducing energy costs. Madlool, Saidur, Hossain, and Rahim (2011) show that companies that manufacture cement have energy consumption totaling 29% of the total cost, with grinding being the largest consumer of electricity, at about 38%. The activity performed by the maintenance department in equipment lubrication can reduce the electric energy consumption of an electric motor by 1% to 2% (Saidur, 2010). The numbers shown give a dimension of how the maintenance department has a direct relationship in reducing the costs of production.

The evolution of industry is composed of four distinct ages. The first revolution had water and steam as its base. The second revolution introduced electricity. The third revolution is identified by the addition of automation. The fourth revolution is based on cyber-physical systems (Borlido, 2017). As machines evolved from steam-generated movements to the present day where machines can be operated through the Internet, asset management has also evolved. A maintenance department, which started in the early 1900s in the US, brought maintenance policies from focusing on corrective actions to placing emphasis on preventive actions, and further improved with condition-based maintenance (Katicic & Lovrincevic, 2012). Those evolutions were motivated because of the evolution of machines. Other techniques, such as reliability centered maintenance (RCM) (Schneider et al., 2006) (Woodhouse, 2007), total productive maintenance (TPM) (Tywoniak, Rosqvist, Mardiasmo, & Kivits, 2008), and overall effectiveness equipment (OEE) (Sherwin, 2000) (Kao, Chang, Dauzere-Peres, & Blue, 2016) were developed to support asset management.

The principle of operation of the technology brought about by Industry 4.0 consists of the following:

- obtaining measured values and converting these physical measures into analyses,
- interpretation of this information and self-correction through self-learning algorithms (in some cases),
- communication and transmission of these data to servers in the cloud, and
- analysis of large volumes of data (Fleischmann, Kohl, & Franke, 2016; Guillén, Crespo, Gómez, & Sanz, 2016).

The most commonly encountered maintenance type that has a major influence on the evolution of Industry 4.0 is predictive maintenance. Spendla, Kebisek, Tanuska, and Hrcka (2017) stated that predictive maintenance can be divided into two sub-categories: statistic-based predictive maintenance and condition-based predictive maintenance.

For instance, Industry 4.0 joined mechanical, electrical, electronic, and information technology and knowledge, and added it to the manufacturing environment. There are no longer clear divisions between those entities. Their performance activities depend on each other in both ways. For example, a robot that is not well maintained can send a wrong message regarding its position, and the software will try to correct it and cause an accident. In another example, software can have a bug and send the incorrect information to a robot, and it can hit something or fail in its task. Soares S. (2017, October 20). Phone Interview.

To avoid sudden failures, engineers have developed preventive maintenance, which aims to intervene with equipment periodically and replace components and make

adjustments and other activities, regardless of the state of conservation and operation of this equipment. Because of equipment downtime and the replacement of parts that are still good, the costs for this technique cannot be reduced (Scheffer & Girdhar, 2004). To reduce downtime and cost and extend the equipment running time until close to equipment failure, a condition-based maintenance or predictive maintenance (PdM) was created.

Predictive actions are those based on the condition of an asset. In ISO 55000: 2014, Mobley (2002) defined predictive maintenance as an action to monitor equipment. If the results do not conform to a specified range, it will trigger a preventive or corrective action. Predictive maintenance has been improved since its first use, based on human senses, such as vision, touch, hearing, and smell. Instruments are used to measure the equipment condition and provide better accuracy to predict failure. Vibration, particle, chemical, physical, temperature, and electrical are six aspects regarding deterioration that PdM is able to detect (Levitt, 2002). Technologically, PdM has been improved over the years. According to Hashemian and Bean (2011), the predictive maintenance measurements can be obtained in three ways: not wired sensors, wired sensors, and wireless sensors. The improvement is identified by the evolution of the kind of sensor to obtain data.

A framework suggested by Fleischmann et al. (2016) in terms of PdM consists of a traffic of data between different technologies, such as the Internet of things (IoT) sensor devices, webservers, PDA, systems in the cloud, big data, self-learning machines, and datasets. Everything from these new technologies brought from Industry 4.0 can be embedded in common equipment. Based on the literature presented so far, even at the

beginning of the fourth industrial revolution it is possible to predict features of future industrial equipment. In terms of mechanical and electrical features, they may gain few improvements. However, in terms of electronic and IT features, they will experience a huge change.

To bring this new technology to a manufacturing plant, a process for systems engineering is triggered. Gulati (2013) argued that there are eight primary functions to support system engineering. Design/development, build/construction/manufacture, deployment/fielding/commissioning, and support/maintenance are functions directly related to implementing Industry 4.0 inside a company. The department in which system engineering is assigned is the engineering department. The system design process will define that technology following the requirements gathered to manufacture a product (Blanchard & Fabrycky, 2011).

When the design is being developed, typically, the functional organization for a manufacturing plant will have a chief of engineering, supervisor of mechanical engineering, supervisor of electrical engineering, and a staff to support the department (Morse & Babcock, 2014). On the other hand, at the third industrial revolution age, the IT department has its own functional organization with initiatives such as Manufacturing Execution System (MES) in the manufacturing environment which requires IT resources to implement it (Chen, Tsai, & Chang, 2006). They are not under the engineering or maintenance departments. They are a shared service for the plant, doing services for HR, administration, finance, and manufacturing. The IT investments are allocated to acquisitions of hardware, software, network, and others, which are related to IT architecture. The basic components of IT architecture are business architecture,

application architecture, data architecture, and technical architecture (Turban, Volonino, & Wood, 2013).

Industry 4.0 brought a new approach to the maintenance point of view with a heavy use of IT hardware and software. They are using PdM as it has never previously been used. To implement traditional PdM, a person qualified and experienced in industrial maintenance with a deep knowledge in diagnosis will need to make decisions based on collected data (Carnero, 2006). In these transition years, the technologies need to be assembled on actual manufacturing equipment. The cost, design know how, and delivery of these technologies are not worth it for the company to do by themselves. A third party will be used to design and deliver these technologies.

As more components are added to a system, these components also have the probability of failure. However, these new components are new technologies, and by nature, more components bring more failure modes. The nature of troubleshooting equipment failures will likely be more complex in Industry 4.0. Wan, Li, Gao, Roy, and He (2016) suggested that a collaborative tool could be used to keep historical data regarding every breakdown. This tool builds a relationship between the equipment, failure mode, effect, and possible and real causes of the equipment failure. This information will serve as a source of knowledge to repair the equipment when a breakdown occurs.

Especially at the beginning of the formation of this database for the equipment brought by Industry 4.0, the knowledge acquired on a day-to-day basis may not be enough to identify the cause and eliminate and repair the equipment in a reasonable time to not compromise the equipment availability. In the opposite direction, Vathoopan,

Brandenbourger, and Zoitl (2016) stated that those who handle the equipment breakdown can be skilled or unskilled. This statement is potentially troublesome for the mission of maintenance departments as there are specific repairs that require only skilled labor due to the embedded technology. In this case, unskilled labor can damage the equipment, fail to repair the equipment, or take an extended time to repair the equipment.

Figure 1 corroborates with the thesis of the steps related to maintaining equipment and the necessary characteristics in relation to knowledge (Fleischmann, Kohl, Franke, Reidt, et al., 2016). For breakdown, just the diagnosis and action steps will be performed.

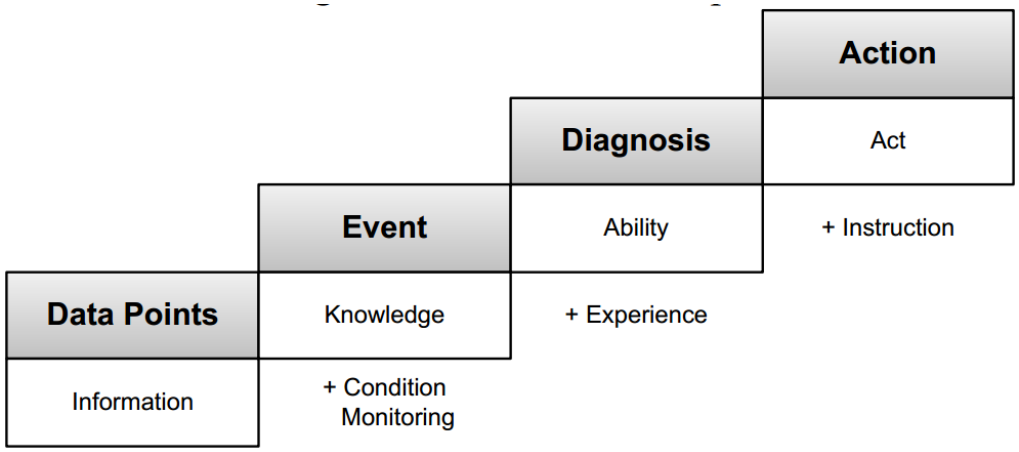

Figure 2.1 Information and characteristics to be used for maintaining equipment. Adapted from Fleischmann, Kohl, Franke, et al., 2016

CHAPTER III

METHODOLOGY

Industry 3.0 introduced electronics through the Programmable Logic Control (PLC) and proprietary software which operates the equipment in the manufacturing environment (Zhou, Taigang Liu, & Lifeng Zhou, 2015). Industry 4.0 brought other technologies such as IoT, machine learning, and others. It is a hardware and software evolution in terms of computers and IT (Papakostas et al., 2016). Professionals from the maintenance department who have been working with Industry 3.0 since the 1960s are now being required to develop new skills to maintain the manufacturing equipment for the Industry 4.0 technologies that are attached to it.

A very common process in manufacturing is that the design department oversees defining, designing, assembling, and delivering equipment (Pahl & Beitz, 2013) and now must have knowledge of Industry 4.0 during these processes. During the delivery phase, the equipment supplier offers training and support materials for those who will operate and maintain the equipment. From that point, operations and maintenance take over the equipment. The maintenance department that has maintained the equipment with Industry 3.0 will now have to maintain the equipment with Industry 4.0 technologies.

Industry 4.0 is a complement to Industry 3.0, with modifications in terms of hardware, IoT devices, and software (Papakostas et al., 2016) whether it is open source or

proprietary. Per literature review so far, we see that the technology in Industry 4.0 is distinct from Industry 3.0, and thus additional knowledge is required from those who will maintain the equipment. The authors suppose that the accumulated knowledge regarding equipment repair in mechanical and electrical terms will change little with the functioning of the equipment in terms of mechanical movements continuing in much the same way. This means that maintenance will continue to perform their current activities.

According to Rü\s smann et al., (2015) a new structure will be required in Industry 4.0 in terms of hardware and software because they will be the main gaps that exist to be filled in the evolution of Industry 3.0 to Industry 4.0. To fill this gap, new knowledge will be needed (Wan et al., 2016). The technology such as IoTs devices, communication platforms, and others embedded in equipment on the Industry 4.0 will change the way to perform the maintenance tasks. Technician skills will be required to be applied in the interpretation of the problems in the hardware used for the communication of data between several platforms and to solve bugs in the software that run for the operation of the equipment.

According to the literature so far, Industry 4.0 is adding new technologies such as IoTs, AI, cloud computing, etc. Those technologies can be understood as components being added to the manufacturing environment. To the best of the author's knowledge, there is not a big difference in the engineering process when new equipment has Industry 4.0 technology embedded in it. With new IT-based technology applied in manufacturing, a new IT infrastructure and new manufacturing-specific software will need to be deployed and installed. Currently, the hardware and software infrastructure are under the responsibility of the IT department with the majority of their focus on administrative

office support. The ratio of manufacturing applications and hardware between Industry 3.0 and Industry 4.0 will increase significantly. This change will bring new challenges to the organizational structure in terms of which department oversees the maintenance for this new infrastructure. The skillsets required for enterprise information technology (IT) and industrial operation technology (OT) are very different (Neil, 2015).The IT department has the knowledge to support the technology such as network, security, system, etc. However, the priority for the IT department before Industry 4.0, has not been manufacturing. On the other hand, manufacturing does not have the knowledge to support the technology, but it aims to prioritize the repair as soon as possible when this technology fails.

To establish an effective plan of action where gaps will be addressed and resolved, it is necessary to know what the current reality is during the transition between Industry 3.0 and Industry 4.0. The investigation will aim to obtain information from the managers/directors and technicians of the maintenance area. Resources such as Linked In, Linked In groups, Industrial Maintenance network, Industrial Maintenance discussion list and Industrial Maintenance blogs will be used as resources to be used on survey. In this way, the results will show the current situation, and the gaps can be identified. Resources such as Linked In, Linked In Groups related to industrial maintenance, Society for Maintenance and Reliability Professionals, other groups related to industrial maintenance and professional network will be used as source for the survey.

The profiles of the maintenance managers/directors and technicians will be surveyed. The goal for the manager/director survey is to obtain information on the following:

- how much they know about Industry 4.0,
- whether they have Industry 4.0-relevant technology already in place,
- what the level of technician expertise is, and
- what knowledge updates for the new technology have been achieved.

For technicians, the goal is to determine their level of general knowledge about Industry 4.0 and how much deeper knowledge of these technologies they may have.

There will be people that work in the maintenance area that do not perform management or execution functions. These people will be classified as managers/directors if they have completed a bachelor's degree or have more than seven years of experience in the maintenance area. Otherwise, they will be considered a technician.

The survey will be conducted through the Internet in the English, Spanish, and Portuguese languages (See Appendix A). A list of the respondents will be made from the discussion groups related to maintenance and from contacts of maintenance people who have already worked with the author.

The research begins by qualifying the respondents in relation to the following:

- type of associated industry,
- relationship of the respondent with the maintenance department,
- number of people in the maintenance department, and
- respondent's position, years of experience in maintenance, and formal education.

In relation to Industry 4.0, the research is developed with questions about the f following items:

- what Industry 4.0 is,
- the current knowledge about the current communication infrastructure,
- whether there are people in maintenance with programming expertise,
- whether they already have technology related to Industry 4.0,
- what the implementation and/or expansion plan is,
- what technology is installed and the extent,
- what training they have had on Industry 4.0, and
- how the knowledge of the technology training is shared among technicians.

Regarding the organization chart, I will also ask the following:

- whether people in the engineering department have Industry 4.0 skills,
- which department is responsible for the specific applications of the manufacturing area,
- which department is responsible for the IT infrastructure applied in the manufacturing environment, and
- what the opinion is regarding the transition of some functions from the IT department to the maintenance department.

Because the questions of a survey can influence the evaluation of responses, simple, clear, and concise questions facilitate understanding and guide the researcher to the answers that most closely match the reality of the respondent. To prevent respondents from becoming confused with questions and answers, a draft of survey questions will be sent to selected people in the manager/director and technician group. The purpose of this

draft is to receive feedback regarding questions that are missing and questions that are difficult to understand.

CHAPTER IV

SURVEY, DATA ANALISYS, AND DISCUSSION

The Survey

This chapter discusses the survey tool used, the survey application period, the efforts to encourage members of maintenance departments to participate in the survey, and the data analysis. This analysis will be demonstrated using tables, graphs, and other resources to make the information more understandable and consumable.

The online survey tool Sogosurvey (www.sogosurvey.com) was used. This tool has a feature that can use three selected languages for the same set of questions, avoiding a mismatch of the questions for each language and ensuring that the questions have the same meaning in each language.

The evolution of Industry 3.0 to 4.0 brought the cyber-physical infrastructure to manufacturing, which was its major improvement. New technology is continually being added to manufacturing equipment, such as IoT devices, big data, machine learning, and so on. Those new technologies need to be maintained, and moreover, they are part of the manufacturing environment in this new age. The main problem for this study is the actual knowledge that the maintenance personnel have regarding Industry 4.0 and the effects that the changes associated with Industry 4.0 will bring to the structural organization of their company.

The Participants

To provide incentive for professionals to fill out the survey, an effort was made to determine the best way to invite people to participate. Individual emails to contacts from the student researcher network were sent in all appropriate languages (see Appendix B). The content of the emails was posted on the LinkedIn groups related to professionals who work in the maintenance department, and other announcements were posted on social media asking for participation. This effort was performed three times, as shown on Graph 1, on Jan. 25, 26, and 30. The survey to collect data to be used in this study was started on Jan. 25, 2018 and ended on Feb. 9, 2018.

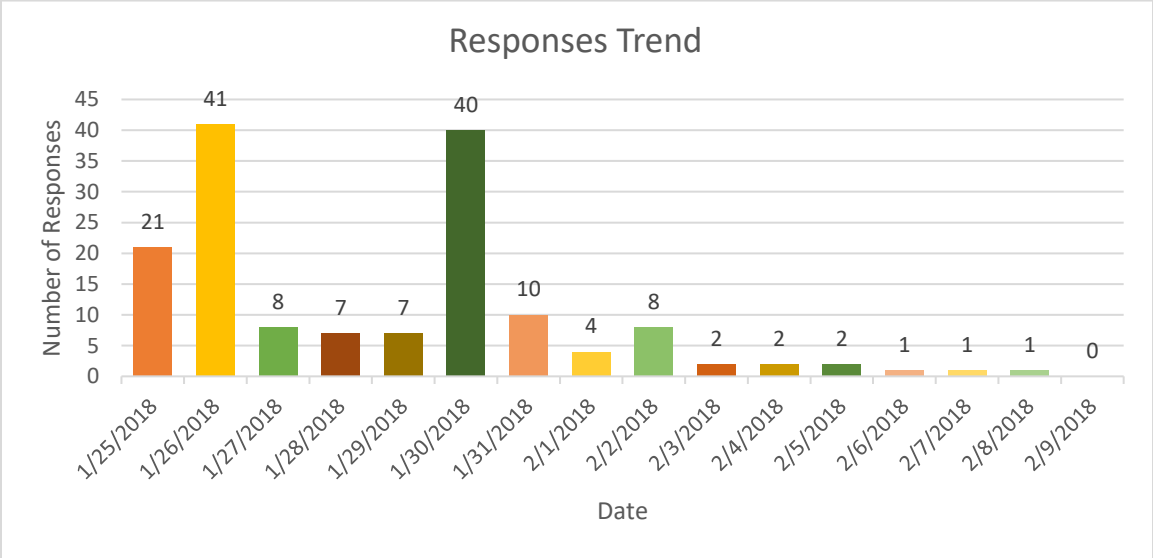

Figure 4.1 Response trend report

A total of 155 participants replied to the survey on the period. Questions not answered, the blank answer was not included the correspondent analysis; in this case, the respondents were still analyzed if he/she answered another question. Ninety-nine respondents (~64%) were from the maintenance department, nine (~6%) from the production department, and 47 (~30%) from other departments (the majority from IT).

Since the target for this study is Maintenance Department, the results seen below will compute just respondents who belong to the maintenance department, an exception on Table 4.13 IT activities migrating to operations technology. Ninety-seven (~99%) of the respondents were men, 58 (~58%) of the respondents considered themselves to be white collar, and 41 (~41%) blue collar. Sixteen (~16%) of the respondents answered "yes" regarding whether they worked under union regulations. Additional statistics are summarized in Table 4.1 Summarized statistics.

Table 4.1 Summarized statistics

Variables	Statistics
Age (mean (SD))	44.36 (10.11)
Years of experience in maintenance	17.62 (9.78)
Gender (No. of participants)	
Male	97
Female	1
Line of Business (No. of participants, *n* (%))	
Transformation	31 (31.63%)
Process	28 (28.57%)
Manufacturing	20 (20.41%)
Service	18 (18.37%)
Utilities	1 (1.02%)
Country your company (site/plant) is located in (*n* (%))	
Brazil	101 (65.16%)
United States of America	35 (22.58%)
Other	19 (12.26%)
If you answered USA on the previous question, what state your company is located in (*n* (%))	
Illinois	5 (19.23%)
Florida	3 (11.54%)
Texas	3 (11.54%)
Georgia	3 (11.54%)
Alabama	2 (7.69%)
Tennessee	2 (7.69%)
Utah	2 (7.69%)
Arkansas	1 (3.85%)
Ohio	1 (3.85%)
Virginia	1 (3.85%)
Wisconsin	1 (3.85%)
Kentucky	1 (3.85%)

The data displayed on this table come from following question(s):

- What is your age?
- How many years have you worked at the Maintenance Department?
- What is your gender?
- What is the type of industry that you currently work?
- What country is your company (site/plant) located?
- If you have answered USA on previous question, What's the state your company (site/plant) is located?

Results and Discussion

In this chapter, the results will be displayed, and the related content will be explained and discussed in detail.

Results

Countries

The answers provided by the respondents regarding their country of residence generated a list of 9 countries. Table 4.2 Responses by country, presents the distribution of population by country.

Table 4.2 Responses by country

	Responses	%
Brazil	62	62.63%
United States of America	26	26.26%
Canada	2	2.02%
United Kingdom	2	2.02%
Trinidad and Tobago	2	2.02%
Argentina	2	2.02%
Egypt	1	1.01%
Mexico	1	1.01%
France	1	1.01%

The data displayed on this table comes from following question(s):

- What country is your company located?

Implementing Industry 4.0 technologies in the future

The question was based on establishing the time frame needed to implement the cyber-physical infrastructure (technologies) at the company where the respondents work.

Table 4.3 Implementing Industry 4.0 technologies in the future

Variables	Responses	%
I don't know	37	54.41%
Next Year	14	20.59%
In two years	8	11.76%
3+ years	5	7.35%
In three years	4	5.88%

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor
- Does your company intend to implement IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines technologies for the manufacturing equipment?

Function in the company

The focus of this study is the impact of Industry 4.0 on maintenance department labor skills.

Table 4.4 Function in the company

Variables	Responses	%
Director/manager/supervisor	88	88.89%
Technician	10	10.10%
IT	1	1.01%

The data displayed on this table come from following question(s):

- What is your function at the Company?

Industry 4.0 knowledge

This data regards the score level of knowledge of Industry 4.0. The score range of the survey was 0 to 5. The source data comes from Question 7: *How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?* The hypothesis for the *t*-test was 2.5; that is, the middle value on a scale of 0 to 5. All answers that received the score zero, it does mean, have no any knowledge on industry 4.0, were discarded for the purpose of statistical analysis. In Table 4.5 Function in the company and Industry 4.0 knowledge, shows data regarding the function of director/manager/supervisor. Table 4.6 Function in the company and Industry 4.0 knowledge for Brazil and USA, displays data from the function of director/manager/supervisor within the countries of Brazil and the USA.

Table 4.7 Blue and white-collar and Industry 4.0 knowledge , came from those respondents that self-identification of being blue or white-collar employees. Table 4.8 Function of director/manager/supervisor who received formal training on Industry 4.0 and Industry 4.0 knowledge, shows results from the function of director/manager/supervisor on whether they received or did not received formal training on Industry 4.0. The last Table, Table 4.9 Function in the company and Industry 4.0 knowledge for LoB (line of business), is related to the function of director/manager/supervisor that indicates their knowledge of Industry 4.0 by Line of Business.

Table 4.5 Function in the company and Industry 4.0 knowledge

	Mean	**SD**	***t*-test results (test value = 2.5)**
Director/manager/supervisor	3.26	1.25	$t = 6.15$, $p < 0.05$

Notes:
One (1.14%) director/manager/supervisor skipped this question;
Eight (9.90%) directors/managers/supervisors answered they don't have any knowledge regarding Industry 4.0.

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor
- How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

Table 4.6 Function in the company and Industry 4.0 knowledge for Brazil and USA

ANOVA results	*N*	Mean	SD	95% CI
Director/manager/supervisor, Brazil	48	3.40	1.30	(3.032, 3.759)
Director/manager/supervisor, USA	22	3.18	1.14	(2.645, 3.719)
Director/manager/supervisor, Other than USA/Brazil	9	3.60	1.35	(2.804, 4.396)

Analysis of Variance

Source	DF	Adj SS	Adj MS	*f*-value	*p*-value
Country	2	1.336	0.6678	0.42	> 0.05
Error	77	123.152	1.5994		
Total	79	124.488			

Notes:
One (1.14%) director/manager/supervisor skipped this question;
Eight (9.90%) directors/managers/supervisors answered they don't have any knowledge regarding Industry 4.0.

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor
- What country is your company located? On answers, used a filter with the criteria to group countries different than Brazil and USA.
- How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

Table 4.7 Blue and white-collar and Industry 4.0 knowledge

	Mean	**SD**	**Two sample *t*-test results**
Blue collar	2.97	1.35	
White collar	3.60	1.14	
			t-value = -2.15, DF = 53, *p*-value < 0.05

Notes:
One white and 1 blue-collar workers skipped this question;
Three white and 6 blue-collar workers answered they don't have any knowledge regarding Industry 4.0.

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor

- Do you consider yourself as a white-collar or a blue-collar worker?
- How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

Table 4.8 Function of director/manager/supervisor who received formal training on Industry 4.0 and Industry 4.0 knowledge

			Two sample *t*-test results
	Mean	StDev	
Didn't receive formal training	3.13	1.29	
Received formal training	4.10	0.81	
t-value = -3.89 DF = 49, *p*-value < 0.05			

Notes:
One (1.14%) director/manager/supervisor skipped this question;
Eight (9.90%) directors/managers/supervisors answered they don't have any knowledge regarding Industry 4.0.

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor

- Have you had formal training regarding IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?
- How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

Table 4.9 Function in the company and Industry 4.0 knowledge for LoB (line of business)

ANOVA results				N	Mean	SD	95% CI
Service				18	3.67	0.97	(3.086, 4.247)
Transformation				26	3.58	1.07	(3.094, 4.060)
Process				23	3.04	1.36	(2.530, 3.557)
Manufacturing				11	2.82	1.66	(2.076, 3.560)
Analysis of variance							
Source	DF	Adj SS	Adj MS		Adj MS		*p*-value
Line of business	4	11.14	2.784		2.784		< 0.05
Error	74	112.94	1.526				
Total	77	124.08					

Notes:
One (1.14%) director/manager/supervisor skipped this question;
Eight (9.90%) directors/managers/supervisors answered they don't have any knowledge regarding Industry 4.0. Utilities had just one sample and was removed from this topic.

The data displayed on this table come from following question(s):

- What is your function at the Company? Filtered by:

  Director/Manager/Supervisor

- What is the type of industry that you currently work?
- How much do you know about IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

White or blue-collar workers in the maintenance department

This data is regarding who identified themselves as white or blue-collar workers. Blue-collar workers are those who work at the shop floor level. In the maintenance department, it means those who perform their work doing maintenance. The white-collar workers are those who work in offices, or those who manage/supervise the blue-collar workers.

Table 4.10 White or blue-collar workers in the maintenance department

Variables	Responses	%
Blue collar	41	41.41%
White collar	58	58.59%

The data displayed on this table come from following question(s):

- Do you consider yourself as a white-collar or a blue-collar worker?

How acquire current technologies shared among technicians

This data regards those whose work is related to the maintenance department and the way they acquire new knowledge and apply it on the job.

Table 4.11 How acquire current technologies among the technicians

Variables	Responses	%
Formal training given by equipment vendor	32	32.99%
Formal training given by expert employee	14	14.43%
Informal training/training on the job	37	38.14%
None	14	14.43%
Notes: 2 (2.02%) respondents answered N/A and were discarded for this analysis.		

The data displayed on this table come from following question(s):

- What are the current technologies shared among the technicians?

Content to support shareable knowledge

This data regards those whose work is related to the maintenance department and which respondents answered *formal training given by expert employee*, *informal training/training on the job*, or *none* to the question about how the technologies are shared among technicians and how the main data source is used to share knowledge.

Table 4.12 Content to support shareable knowledge

Variables	Responses	%
Does exist and is accurate	41	45.05%
Does exist and is not accurate	31	34.07%
Does not exist	19	20.88%

Notes:
One (1.03%) respondents skipped the question and was discarded for this analysis.
Five (5.15%) respondents answered N/A and were discarded for this analysis.

The data displayed on this table come from following question(s):

- What are the current technologies shared among the technicians? Filtered by formal training given by expert employee, informal training/training on the job, or none
- Is there an accurate system for technicians to record fails, causes, effects, solutions and lessons learned to share with other technicians?

IT activities migrating to operations technology

This data is acquired from respondents' perceptions regarding the degree to which they believed that some actual IT activities were migrating to operations technology under the manufacturing organizational chart. There are two points of view: IT-related and non-IT-related respondents. The score range in the survey was 0 to 5. Zero was identified *don't believe at all* and 5 as *strongly believe*.

Table 4.13 IT activities migrating to operations technology

Variables	Statistics
IT-related respondents (mean (SD))	1.67 (1.68)
Non-IT-related respondents (mean (SD))	2.27 (1.68)

Note:
All respondents. The filter regarding Maintenance Department was turned off.

The data displayed on this table come from following survey question(s):

- What is your function at the Company? On answers, used a filter with the criteria: “Other” and on the text field required when the answer is “Other” applied the filter for IT and correlated names.
- How much do you believe that some IT functions to support the manufacturing department, such as hardware infrastructure (networks, manufacturing desktops) and software support, will be transferred to the manufacturing/maintenance department?

Engineering/design department bringing Industry 4.0 technology to the company

This data is acquired from the perception of respondents in the maintenance department regarding how much they believe the people from the engineering/design department know about Industry 4.0. The score range in the survey was 0 to 5. Zero - Do not believe and 5 - Strongly believe

Table 4.14 Perception from Maintenance Department regarding Industry 4.0 knowledge of Engineering Department

Variables	Statistics
Perception about engineering knowledge regarding Industry 4.0 (mean (SD))	2.51 (1.62)

The data displayed on this table come from following question(s):

- How much does the engineering (design, develop and deploy equipment) group have people with knowledge of IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines?

Discussion

The Table 4.1 Summarized statistics, shows a Summarized Statistics, and the first important information was gained from the question *How many years have you worked in the maintenance department?* A mean of 17.62 years and standard deviation (SD) of 9.78 years, and the question *What is your age?* presents a mean of 44.36 years and SD of 10.11 indicates that the survey population was very heterogeneous and, which are beneficial statistics for this study.

The results of the survey that asks about the profile of the respondents in relation to the position they hold confirms the perception that blue-collar workers still maintain a distance from technology. About 89% of the respondents, displayed in 0

Function in the company, answered that they were a director/manager/supervisor. Ten percent answered that they were a technician. Another interesting fact connected to these two groups appeared in the answer of how respondents identified themselves in relation to white collar and blue collar. The professionals identified as directors, managers, and supervisors usually worked in the office and were called white collar. The distribution of white to blue collar should be similar to the distribution of director/manager/supervisor to technician. Instead of being approximately distributed 90% and 10% as was expected, the distribution of white to blue collar was 59% and 41% (Table 4.10 White or blue-collar workers in the maintenance department). Although there is this discrepancy, the outcome of the study was not affected.

Being familiar with the current situation about Industry 4.0, from the perspective of knowledge on the subject, how to prepare, the infrastructure necessary to succeed in learning, the current technology that other companies are using in Industry 4.0, the

knowledge of the professionals who are bringing these technologies into manufacturing, and when that will happen, is a fundamental part of this study.

Regarding the knowledge of Industry 4.0 and its technologies, on a six-point scale, zero being assigned as “no knowledge” and five being assigned to “deep knowledge,” different analyses were performed; About 9.2% of directors, managers, and supervisors say their knowledge of Industry 4.0 was zero. The zero-knowledge responses were discarded from the statistical evaluations related the knowledge in Industry 4.0, the *t*-test mean for that group was 3.26, with a 1.25 standard deviation denotated in Table 4.5 Function in the company and Industry 4.0 knowledge. The two countries that had the majority of respondents, Brazil and USA (Table 4.2 Responses by country), have similar mean and standard deviation with 3.40, 1.30 for Brazil and 3.18, 1.14 for USA shown at Table 4.6 Function in the company and Industry 4.0 knowledge for Brazil and USA. ANOVA results indicate a p-value > 0.05, indicating the country does not make any difference for knowledge on Industry 4.0. The author’s initial expectation was that the USA should have a higher mean than Brazil due to the fact that this technology takes longer to arrive in South America than it does to arrive in the USA.

The directors, managers, and supervisors working in LoB Service, Transformation and Process had the mean on range 3.04 to 3.67, displayed in Table 4.9 Function in the company and Industry 4.0 knowledge for LoB (line of business), for their means, 3.67, 3.58 and 3.04, respectively, and standard deviations of 0.97, 1.07 and 1.14, respectively. The fact of LoB Manufacturing stay behind with Mean and standard deviation values 2.82 / 1.66 rise an observation because the Industry 4.0 have been working on LoB Manufacturing as well.

When new technology is taking effect, some lines of business (LoBs) tend to be the first to get, learn, and apply such an advantage. ANOVA was applied to the LoB (Table 4.9 Function in the company and Industry 4.0 knowledge for LoB (line of business)) regarding knowledge for Industry 4.0, and $p < 0.05$ denoting the line of business for respondents of this survey does influence on knowledge of Industry 4.0.

Regarding the blue and white-collar categorizations, given by the table Table 4.7 Blue and white-collar and Industry 4.0 knowledge, the mean for their knowledge ranking was 2.97 for blue collar and 3.60 for white collar, with standard deviation of 1.35 for blue collar and 1.14 for white collar. This gap in terms of knowledge is marked for who received formal training and those who did not; it resulted in a mean of 4.11 and standard deviation 0.81 compared with 3.13 and standard deviation 1.29 for those without formal training, displayed in the Table 4.8 Function of director/manager/supervisor who received formal training on Industry 4.0 and Industry 4.0 knowledge . The *p*-value found on blue and white-collar respondents was $p < 0.05$, and received/didn't receive formal training as $p < 0.05$, denoting that both variables influence Industry 4.0 knowledge. Another important observation from this analysis is that the mean increased when professionals took formal training, and the professionals who fix the equipment, the blue-collar workers, have the lowest mean. Because this population is the key factor to re-establishing equipment in the case of failure, the appropriate training program will help to reduce equipment downtime when in failure mode, and one of the challenges that will be faced in the implementation of Industry 4.0 will be to teach how equipment fails, how to repair it, lessons learned, and so on.

Industries, in general, offer informal and on-the-job training. The content of this training should be available, correct, and up-to-date. The population who work in maintenance who responded to the survey said that they received formal training given by an expert employee, informal training/training on the job, or none. If an accurate system does not exist for the technicians to record failures, causes, effects, solutions, and lessons learned, of the ability to share this knowledge with other technicians will be at risk. Given by Table 4.12 Content to support shareable knowledge, 45% of this population responded that there is a system and that it is accurate; 34% responded that the system exists but it is not accurate; 21% responded that the system does not exist. This information draws attention because the total amount of 53% of the technicians which receive training given by their company or training on the job (Table 4.11 How acquire current technologies among the technicians) is exposed to system which the content does not exist or is not accurate in 52% displayed in Table 4.12 Content to support shareable knowledge.

To bring a technology related to Industry 4.0 to a manufacturing company, the engineering/design department must specify the equipment and the technology assigned to it. Respondents who self-identified as maintenance workers were asked their perception of Industry 4.0 knowledge that people from engineering/design had. The Table 4.14 Perception from Maintenance Department regarding Industry 4.0 knowledge of Engineering Department Their within a range of 0 to 5, showed a mean of 2.51 and SD of 1.62.

And the future? The survey asked when the technologies would be applied to the respondents' respective companies. Displayed in Table 4.3 Implementing Industry 4.0

technologies in the future, respondents classified as directors, managers, supervisors, who answered, “next year,” “in two years,” and “in three years,” totaled 38%; 54% responded “I don’t know.” This number should raise a red flag for Industry 4.0, as well as for the responders. The ratio is related to knowledge about Industry 4.0, which is given 3.26 out of 5, where 5.0 does mean deep knowledge (Table 4.5 Function in the company and Industry 4.0 knowledge). It seems there is a vicious cycle: they do not introduce the technology because they are not familiar with it; they are not familiar with the technology because they do not have it; and so on.

The future is still coming, and organizations need to be prepared for the changes and impacts Industry 4.0 will bring to manufacturing companies. A question regarding operation technology (OT) was presented in the questionnaire to assess the respondents’ perceptions about some activities under the IT department, left the IT department and went to the OT department, which is included under the manufacturing/maintenance organizational chart. Two points of view were presented: one from respondents who already work in the IT department, the other from respondents who do not work in the IT department. On a six-point scale, which zero figure as don’t believe and 5 is strongly believe, the Table 4.13 IT activities migrating to operations technology shows that IT-related respondents have a mean of 1.67 and SD of 1.68. The reasons why the IT workers did not believe that some activities went to OT were not asked to specify these in the survey. For non-IT-related respondents, the mean is 2.27 and SD 1.68. Although this is higher than for the IT workers, it is still under 2.5 points, which represents 50%.

CHAPTER V

CONCLUSION

The Industry 4.0 evolution is bringing new technologies to the manufacturing arena. These new technologies require new skills in areas such as IT, engineering/design, manufacturing, and maintenance. This study has focused on the maintenance field. At this point in the evolution of Industry 4.0, maintenance workers, both white and blue collar, have a lack of knowledge of Industry 4.0 in terms of concept and infrastructure, and data analysis indicates that the categories of white collar or blue collar and did take or didn't take formal training heavily influence Industry 4/0 knowledge.

Filling the gap in knowledge will generate some impact, since the main way to acquire knowledge, as revealed by the survey, is informal and on-the-job training. The information system to be used to support this knowledge transfer needs to be improved.

The technology in place regarding Industry 4.0, such as temperature, pressure, humidity, ultrasound, and vibration analysis, follows the industry on the third revolution, but with cyber-physical characteristics, which is the main distinction from Industry 3.0 as stated on the literature presented on this study.

Measurement devices, sensors, and advanced algorithms can give equipment conditions for its life, but the execution of the maintenance on these new devices must be done by a human being in the majority of cases. Because of this, training is key to

acquiring the best results for maintenance. The survey's results and the data analysis point to providing training regarding Maintenance 4.0 for professionals who work in maintenance departments, regardless of their function, country, LoB, and so on.

All this transformation should be followed by a very structured change in management plans, so as to get the expected results and a smooth implementation.

The survey for responders from the IT department (Table 4.13 IT activities migrating to operations technology), shows that some actual activities from IT will not go to OT under the manufacturing organizational structure. The points suggested for future research are: (1) conducting a deep study of trending IT activities migrating to OT; (2) in the case where the trend shows that activities will not go to OT, establishing how IT will prioritize and organize their activities to guarantee an acceptable SLA (service-level agreement) when machines fail due to IT technology failures; (3) learning how they are structured to perform preventive or predictive maintenance on these cyber-physical elements; and (4) understanding what types of activities and methodologies will support these preventive/predictive plans.

Opportunities for improving the survey were identified. The question regarding "What is your function at the Company?" had the answer "Director/Manager/Supervisor" which limited some additional analysis. The suggestion is to break the answer into individual answers such as Director, Manager, and Supervisor. Regarding the scales used to determine mean, standard deviation. etc, a description for each value is necessary to help the respondents provide an accurate answer.

Even though the survey had 99 respondents belonging to the maintenance department, the amount of those who were considered Technician was nine people (~10%) displayed in 0

Function in the company. This didn't give the results confidence in the analysis and it was not possible to measure their knowledge level of Industry 4.0.

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APPENDIX A

QUESTIONNAIRIES LANGUAGUES

Table A.1 English Questionnaire: Questions & Answers Options

Order	#	Classification	Question	Answer Type	List	Note
1	3	Personnel	What department do you work or are related to?	List	Maintenance Production Other	N/A
2	2	Personnel	Function at the Company	List	(a) Director / Manage / Supervisor (b) Mechanic Technician / Mechanic Inspector (c) Electronic Technician / Electronic Inspector (d) Electrician Technician / Electrician Inspector (e) Calibration Technician (f) Planner / Scheduler / Store room (g) Other: _____	N/A
3	4	Personnel	How many years have you worked at the Maintenance Department?	Number	( ) N/A when has no experience in maintenance	N/A
4	21	Personnel	Highest level of formal education	List	( ) GED/High School ( ) College ( ) Bachelor ( ) Master/PhD/Post Doc. ( ) N/A	N/A

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5	1	Company	Type of industry that you currently work	List	Aerospace Apparel and Footwear Automotive Auto-Parts Chemicals Consulting Consumer Products & Wholesale Industries Discrete Manufacturing Education / Research Food and Beverage Healthcare Industrial Machinery & Components Medical Devices Mining Oil & Gas Pharmaceuticals Retail Services Industries Material Handling Other: _____	N/A
6	5	Company	How many people work at the maintenance department at your company?	List	07..10 11..20 21..50 51..100 100+ N/A	N/A
Industry 4.o is recognized by bring new technologies to the manufacturing environment. These technologies can be IoT (Internet of Things) devices, communication platform where transmit data directly from the machine to the cloud, cloud computing, self-learning machines, and others.						

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7	6	Knowledge 4.0	How much do you know about Industry 4.0?	Weight (0-5)	N/A	(1)
8	7	Knowledge 4.0	How much do you know how the communication platform works in Industry 4.0?	Weight (0-5)	N/A	(1)
9	13	Knowledge 4.0	What are the current technologies shared among the technicians?	List	(a) Formal training given by equipment vendor (b) Formal training given by expert employee (c) Informal training / training on-the-job (d) Other:_____ (e) None (f) N/A	N/A
10	15	Knowledge 4.0	Have you had formal training regarding Industry 4.0?	List	(a) Yes (b) No	N/A
11	14	Knowledge 4.0	Is there an accurate system for technicians to record fails, causes, effects, solutions and lessons learned to share with other technicians?	List	(a) Does exist and it's accurate (b) Does exist and it's NOT accurate (c) Does not exit (d) N/A	N/A
12	18	Technology	Does your company have machines with the technology of Industry 4.0 which monitors on-line parameters from operations conditions such as vibration, temperature, etc?	List	(a) Yes (b) No (c) I don't know (d) N/A	If no, jump to #20

Error! Reference source not found. (continued)

13	16	Technology	Does your company have manufacturing machines that send on-line data from operations information conditions such as vibration, temperature, etc, to the cloud computing?	List	(a) Yes (b) No (c) I don't know (d) N/A	N/A
14	19	Technology	What is the technology from Industry 4.0 that your company has*? * All answers are related to monitoring on-line and sending information to big-data analysis	List Multiple Option	( ) Vibration analysis ( ) Temperature ( ) Pressure ( ) Humidity ( ) Other: Explain: _____	N/A
15	20	Technology	Does your company intend to implement Industry 4.0 technologies for the manufacturing equipment?	List	( ) Next Year ( ) In two years ( ) in three years ( ) 3+ years ( ) N/A	N/A
16	8	Knowledge 4.0	Are there people assigned to the maintenance department that are able to resolve bugs on the systems when they occur on the manufacturing equipment?	List	(a) Yes (b) No (c) N/A	N/A

Error! Reference source not found. (continued)

17	10	Management	Currently, which department is responsible to maintain the hardware infrastructure for the manufacturing department? (networks, manufacturing desktops)	List	(a) IT Department (b) IT Department with resources under management Manuf./Maint. department (c) Manuf./Maint. department (d) Other: _____ (e) N/A	N/A
18	11	Management	Currently, which department is responsible to maintain the software for manufacturing?	List	(a) IT Department (b) IT Department with resources under management Manuf./Maint. department (c) Manuf./Maint. department (d) Other: _____ (e) N/A	N/A
19	9	Management	How much do you believe that some IT functions to support the manufacturing department, such as hardware infrastructure (networks, manufacturing desktops) and software support, will be transferred to the manufacturing/maintenance department with Industry 4.0?	Weight (0-5)	Weight (0-5)	(2)

Error! Reference source not found. (continued)

20	12	Knowledge	How much does the engineering (design, develop and deploy equipment) group have people with knowledge of Industry 4.0?	Weight	(a) N/A for company which has no Engineering Department Weight (0-5)	(1)
21	22	Personnel	What is your age?	Number	N/A	N/A
22	25	Company	What's the country that the place you work is located?	List	Country List	N/A
23	30	Personnel	Gender	List	N/A	N/A
24	35	Personnel	Do you consider yourself as white collar or blue collar	List	(a) White collar (b) Blue collar	N/A
25	40	Personnel	What state in USA do you work?	List	List of USA states and N/A	N/A
26	45	Personnel	Do you work under Union regulations?	List	(a) Yes (b) No	N/A

(1) 0 for no knowledge and 5 for deep knowledge
(2) 0 - Do not believe 5 - Strongly believe

Table A.2 Spanish Questionnaire: Questions & Answers Options

Or	#	Classificacion	Question	Tipo de la respuesta	Lista	Nota
1	3	Personal	En que departamento trabaja o esta vinculado?	Lista	Mantenimiento Producción Otro	N/A
2	2	Personal	Función dentro de la empresa?	Lista	(a) Director / Gerente / Supervisor (b) Técnico Mecánico / Inspector Mecánico (c) Técnico Electrónico / Inspector de Electrónica (d) Técnico Electricista / Inspector Electricista (e) Técnico Calibrador (f) Planificado / Programador / Encargado de Almacén (g) Otro: _____	N/A
3	4	Personal	Cuantos años has trabajado en la Gerencia de Mantenimiento	Número	( ) N/A cuando no tiene experiencia en Mantenimiento	
4	21	Personal	Mayor nivel de educación	Lista	( ) Primaria ( ) Secundaria ( ) Universitario ( ) Master / Doctorado ( ) N/A	N/A

Table A.2 (continued)

5	1	Empresa	Tipo de industria en la que trabaja actualmente	Lista	Aeroespacial Textil / Calzado / Indumentaria Automotriz Autopartista Química Consultora Consumo masivo Producción a pedido Educación/Investigación Alimenticia Medicina Máquinas pesadas Instrumental Médico Minería Petróleo y Gas Farmacéutica Servicios Naval Agropecuaria Otro: _____	N/A
6	5	Empresa	¿Cuántas personas trabajan en mantenimiento en su empresa?	Lista	07..10 11..20 21..50 51..100 100+ N/A	N/A
7	6	Conocimiento 4.0	Conoce Industry 4.0?	Valoración (0-5)	N/A	(1)
8	7	Conocimiento 4.0	Sabe como la plataforma de comunicación trabaja en Industry 4.0?	Valoración (0-5)	N/A	(1)

Table A.2 (continued)

9	13	Conocimiento 4.0	Como se conocen las nuevas tecnologías entre los técnicos de su empresa ?	Lista	(a) Capacitación formal dada por el proveedor del equipo (b) Capacitación formal dada por un empleado experto (c) Capacitación informal / Capacitación "on the job" (d) Otra: _____ (e) Ninguna (f) N/A	
10	15	Conocimiento 4.0	Tiene capacitación formal en Industry 4.0?	Lista	(a) Si (b) No	N/A
11	14	Conocimiento 4.0	¿Hay un Sistema preciso para que los técnicos puedan registrar fallas, causas, efectos, soluciones y lecciones aprendidas para compartir con otros técnicos de la empresa?	Lista	(a) Does exist and it's accurate. (b) Does exist and it's NOT accurate. (c) Does not exit (d) N/A	N/A
12	18	Tecnología	La empresa cuenta con maquinas que poseen tecnología Industry 4.0, la cuál monitorea en forma permanente y en tiempo real los parámetros operativos como ser vibración, temperatura, presión, etc.?	Lista	(a) Si (b) No (c) No lo se (d) N/A	Si no, vaya al número 20

Table A.2 (continued)

13	16	Tecnología	¿La empresa cuenta con equipos que manden en tiempo real y en forma automática datos sobre la condición operativa de los equipos, como ser vibración, temperatura, presión, etc. a sistemas en la nube?	Lista	(a) Si (b) No (c) No lo se (d) N/A	N/A
14	19	Tecnología	Que tecnología de la utilizada en Industry 4.0 su empresa tiene? • Todas las respuestas relativas al monitoreo en tiempo real y el envio de la información para análisis de grandes volúmenes de información	Lista Multiple Option	( ) Vibraciones ( ) Temperatura ( ) Presión ( ) Humedad ( ) Otros: Explique: _____	N/A
15	20	Tecnología	Esta su empresa intentando implementar tecnología de Industry 4.0 para sus equipos?	Lista	( ) Proximo año ( ) En dos años ( ) En tres años ( ) 3 + años ( ) N/A	N/A
16	8	Conocimiento 4.0	Esta el personal de mantenimiento preparado para resolver problemas cuando ocurren errores en los sistemas de control de los equipos ?	Lista	(a) Si (b) No (c) N/A	N/A

Table A.2 (continued)

17	10	Gestión	Actualmente, que departamento es responsable por mantener la infraestructura de sistemas del departamento de producción (redes, computadoras, impresoras, monitores)	Lista	(a) Departamento de Sistemas (b) Departamento de Sistemas con recursos que dependen del departamento de Operaciones o Mantenimiento (c) Operaciones / Mantenimiento (d) Otro: _____ (e) N/A	N/A
18	11	Gestión	Actualmente, que departamento es responsable por mantener el software (programas) que se utilizan en Producción?	Lista	(a) Departamento de Sistemas (b) Departamento de Sistemas con recursos que dependen del departamento de Operaciones o Mantenimiento (c) Operaciones / Mantenimiento (d) Otro: _____ (e) N/A	N/A
19	9	Gestión	Ud cree que alguna de las funciones de soporte de tecnología, como ser la infraestructura de redes, computadoras, impresoras, monitores y los sistemas que usa el departamento de Producciòn deberían ser transferidos a los departamentos de Producciòn/Mantenimiento con Industy 4.0?	Valoración (0-5)		(2)

Table A.2 (continued)

20	12	Conocimiento	Tiene el grupo de ingenieros (los que diseñan, desarrollan y construyen los equipos) conocimiento de Industry 4.0?	Valoración (0-5)	(a) N/A para Empresas que no tengan un departamento de ingenieria	(1)
21	22	Personal	Edad ?	Número	N/A	N/A
22	25	Empres	Que país está localizado la empresa que trabaja?	Lista	Lista de Paises	N/A

(1) 0 significa que no lo conoce y 5 que posee un conocimiento profundo
(2) 0 – No lo creo 5 – Estoy seguro de que si

Table A.3 Portuguese Questionnaire: Questions & Answers Options

Ordem	#	Classificação	Questão	Tipo da Resposta	Lista	Nota
1	3	Pessoal	Qual departamento você está associado?	Lista	Manutenção Produção Outro	N/A
2	2	Pessoal	Sua função na Empresa	Lista	(a) Diretor / Gerente / Supervisor (b) Mecânico de Manutenção / Inspetor Mecânico (c) Eletrônico de Manutenção / Inspetor Eletrônico (d) Eletricista de Manutenção / Inspetor Eletricista (e) Instrumentista (f) Planejador / Programador / Técnico de Sobressalentes (g) Outro: _____	N/A
3	4	Pessoal	Quantos anos você trabalhou no departamento de manutenção?	Numero	( ) N/A Quando nunca trabalhou na manutenção	N/A
4	21	Pessoal	Qual seu grau de formação escolar?	Lista	( ) Segundo Grau complete ( ) Bacharel/Licenciatura ( ) Mestrado/PhD/Post Doc. ( ) N/A	N/A

Table A.3 (continued)

5	1	Empresa	Tipo de indústria que você trabalha atualmente	Lista	Aeroespacial Alimentos e bebidas Automotivo Autopeças Consultoria Dispositivos médicos Educação / Pesquisa Gás e petróleo Hospitais, clínicas e redes de saúde. Indústria de serviços Manufatura discreta Máquinas e componentes industriais Mineração Produtos de consumo e indústrias de atacado Produtos farmacêuticos Produtos químicos Varejo Vestuário e calçado Outro: _____	N/A
6	5	Empresa	Quantas pessoas trabalham no departamento de manutenção da sua empresa?	Lista	(a) 07..10 (b) 11..20 (c) 21..50 (d) 51..100 (e) 100+ (f) N/A	N/A
7	6	Conhecimento 4.0	Você tem conhecimento sobre Indústria 4.0?	Peso (0-5)	N/A	(1)
8	7	Conhecimento 4.0	Você sabe como funciona a plataforma de comunicação que trabalha na Indústria 4.0?	Peso (0-5)	N/A	(1)

Table A.3 (continued)

9	13	Conhecimento 4.0	Como as novas tecnologias são disseminadas no departamento de manutenção?	Lista	(a) Treinamento formal dado por um fornecedor externo. (b) Treinamento formal dado por empregado experiente. (c) Treinamento informal / Treinamento on-the-job (Treinamento na prática) (d) Outro: _____ (e) Nenhum (f) N/A	N/A
10	15	Conhecimento 4.0	Você teve algum treinamento formal sobre Indústria 4.0?	Lista	(a) Sim (b) Não	N/A
11	14	Conhecimento 4.0	Há um Sistema com informações confiáveis onde os eletrônicos, eletricistas e mecânicos de manutenção possam gravar informações de falhas tais como causas, efeitos e soluções e lições aprendidas para que possa compartilhar estas informações com outros eletrônicos, eletricistas e mecânicos de manutenção ?	Lista	(a) Existe e é confiável. (b) Existe e NÃO é confiável. (c) Não existe (d) N/A	N/A

Table A.3 (continued)

12	18	Tecnologia	Sua empresa tem equipamentos de manufatura que possuem tecnologia da indústria 4.0 ao qual estão presentes monitoramento on-line de parâmetros de operação tais como vibração, temperatura, pressão, etc	Lista	(a) Sim (b) Não (c) Não sei (d) N/A	Se não, pule para #20
13	16	Tecnologia	Sua empresa tem equipamentos de manufatura que envia dados, de maneira on line, sobre parâmetros de operação tais como vibração, temperatura, pressão, etc. para sistemas localizados na nuvem?	Lista	(a) Sim (b) Não (c) Não sei (d) N/A	N/A

Table A.3 (continued)

14	19	Tecnologia	Quais são as tecnologias vindas da indústria 4.0 que sua empresa utiliza*? *As tecnologias assinaladas obrigatoriamente estão on-line e enviando dados a um grande banco de dados instalados na nuvem.	Lista com múltipla escolha	( ) Análise de vibração ( ) Temperatura ( ) Pressão ( ) Umidade ( ) Outro: Explicar: _____	N/A
15	20	Tecnologia	Sua empresa tem intenção de implementar tecnologias da indústria 4.0 nos equipamentos de manufatura?	Lista	( ) No próximo ano. ( ) Em dois anos. ( ) Em três anos. ( ) Mais de três anos ( ) N/A	N/A
16	8	Conhecimento 4.0	Há pessoas do departamento de manutenção capazes em resolver Bugs de sistemas informatizados e programas quando estes problemas ocorrem no Sistema que controla um equipamento de manufatura?	Lista	(a) Sim (b) Não (c) N/A	N/A

Table A.3 (continued)

17	10	Gerenciamento	Atualmente, qual departamento é responsável pela infraestrutura de hardware (Rede, computadores utilizados pelas máquinas de manufatura) relacionados diretamente à área de produção?	Lista	(a) Departamento de IT (b) Recursos do departamento de IT com recursos sob o gerenciamento do departamento de Manufatura/Manutenção. (c) Departamento de Manufatura/Manutenção (d) Outro: _____ (e) N/A	N/A
18	11	Gerenciamento	Atualmente, qual departamento é responsável pelo suporte dos aplicativos relacionados diretamente à área de produção?	Lista	(a) Departamento de IT (b) Recursos do departamento de IT com recursos sob o gerenciamento do departamento de Manufatura/Manutenção. (c) Departamento de Manufatura/Manutenção (d) Outro: _____ (e) N/A	N/A
19	9	Gerenciamento	Você acha que algumas funções de TI para apoio ao departamento de manufatura, tais como Hardware, Infraestrutura (Rede, computadores usados para operar o equipamento) e suporte a software dedicado para manufatura será transferido para o departamento de produção ou manutenção com a entrada da indústria 4.0?	Peso (0-5)	Peso (0-5)	(2)

Table A.3 (continued)

20	12	Conhecimento	Há pessoas no grupo de Engenharia da sua empresa com conhecimento da indústria 4.0?	Peso (0-5)	(a) N/A para Empresa que não tem departamento de Engenharia Peso (0-5)	(1)
21	22	Pessoal	Qual sua idade?	Numero	N/A	N/A
22	25	Empresa	Qual país está relacionado à sua empresa	Lista	Lista de Países	N/A

(1) 0 – Não tem conhecimento 5 – Profundo conhecimento
(2) 0 – Não acredita 5 – Acredita profundamente

APPENDIX B

SURVEY INVITE LETTERS

English survey invite letter

Hi Name,

I'm graduating this semester and my thesis is about the Industry 4.0 related to the maintenance department. My master degree is at the Mississippi State University which is researching the influence of Industry 4.0 on Maintenance Department labor. One of the phases of this research is to apply a questionnaire of 26 questions. These questions require simple answers. The survey is anonymous and you will not be asked to provide any personal information including the name of the company that you work for.

We ask you to participate in this questionnaire to contribute to the science dedicated to the Industry / Manufacturing field. Please forward this message and link to the questionnaire to your contacts network and include professionals who work in the industry/manufacturing and particularly those who work in the maintenance department.

The questionnaire is available in three languages: English, Spanish and Portuguese.

To fill the questionnaire, please click this link or copy and paste the address below:

https://survey.sogosurvey.com/r/SGedWr

The questionnaire will be available until 11:59 pm on February 9th, 2018

Thank you for your collaboration

Tomas Marzullo

Mississippi State University

tm2125@msstate.edu

tmarzullo@tomasmarzullo.com

Cell: +1 (402) 452-7162

Spanish survey invite letter

Hola Nome,

La Universidad Estatal de Mississippi, ubicada en los Estados Unidos, está conduciendo una investigación sobre la influencia de la Industria 4.0 en la mano de obra del Departamento de Mantenimiento. Una de las fases de la investigación es aplicar un cuestionario de 26 preguntas de simple respuesta donde no es necesario ninguna identificación personal o del nombre de su empresa, la investigación es totalmente anónima.

Le pedimos que participe en este cuestionario para contribuir con la ciencia dedicada al área de la industria. Otro pedido que le haremos es que remita este mensaje a su red de contactos, principalmente para profesionales que trabajen en la industria y sería ideal enviarlo a aquellos que trabajan particularmente en el departamento de mantenimiento.

El cuestionario está en tres idiomas: Español (Spanish), Portugués (Portuguese) y Inglés (English). Elija la que corresponda antes de empezar el cuestionario.

Para participar haga clic en este link o copie y pegue la siguiente dirección

https://survey.sogosurvey.com/r/SGedWr

El cuestionario estará disponible hasta 23:59h del día 09 de febrero de 2018.

Desde ya, gracias por su colaboración.

Tomas Marzullo

Mississippi State University

tm2125@msstate.edu

tmarzullo@tomasmarzullo.com

Cell: +1 (402) 452-7162

Portuguese survey invite letter

Olá Nome,

Eu estou graduando este semestre e minha tese é sobre a Indústria 4.0 relacionada a área de manutenção. O meu curso de mestrado é pela Universidade Estadual do Mississippi, localizada nos EUA, ao qual está conduzindo uma pesquisa sobre a influência da Indústria 4.0 sobre mão de obra da área do Departamento de Manutenção. Uma das fases da pesquisa é aplicar um questionário de 26 perguntas de simples respostas e que não será necessária qualquer identificação pessoal ou do nome de sua empresa, o questionário é totalmente anônimo.

Pedimos que você participe deste questionário para contribuir com ciência dedicada a área da indústria. Outro pedido que lhe faremos é que encaminhe esta mensagem para sua rede de contatos, principalmente para profissionais que trabalhe na indústria e seria melhor ainda enviar para aqueles que trabalham no departamento de manutenção.

O questionário está em três idiomas: Português, Espanhol e Inglês. Escolha o seu idioma seu correspondente ao iniciar a pesquisa.

Para participar do questionário clique link abaixo ou copie e cole o endereço:

https://survey.sogosurvey.com/r/SGedWr

O questionário ficará no ar até 23:59h do dia 09 de fevereiro.

Desde já, agradeço por sua colaboração.

Tomas Marzullo

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