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THE CONCEPT OF THE INDUSTRY 4.0 IN A GERMAN MULTINATIONAL INSTRUMENTATION AND CONTROL COMPANY: A CASE STUDY OF A SUBSIDIARY IN BRAZIL

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ABSTRACT

The study aims to present the industry's 4.0 concepts and facilities available on the market, applied in a German instrumentation and control industry in Brazil. The study aims to present advanced manufacturing technologies that are already being applied in the company studied. As a research method, a bibliographic review is done first, followed by a qualitative analysis of the results of a case study. The results are intended to present the company's maturity level in relation to Industry 4.0 (I.4.0) as well as to diagnose possible new applications to increase the control and monitoring of its activities. At the end of the paper, suggestions for future studies will be available to complement the methodology proposed in this study.

Keywords: Industry 4.0, advanced manufacturing, case study

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1. INTRODUCTION

According to Vermulm and Erber (2002), the capital goods sector can be defined as one that manufactures machines and equipment that will be used by other sectors in order to produce goods and services. On the other hand, manufacturing companies are working in an increasingly competitive environment, where large companies compete for market shares with smaller companies and often the gap is related to small details.

According to the context shown in the previous paragraph, with regard to technological development, I.4.0 seeks a (r)evolution in the way of integrating its processes with its data within cyber-physical-space (CPS). Accuracy in the collection and analysis of data is becoming increasingly sought by companies, with the objective of a correct decision-making fostered by challenges arising from the competitive environment in which the company is inserted.

It is expected that the Internet and connectivity exist as a catalyst that tend to group the classic communication networks with the object of sharing and dissemination of available information. All services and content will have mutual connectivity, paving the way for new ways of working, ways of interacting, generating entertainment, as well as evolving into a new concept of how we deal with old habits in cyber-space. The Internet will become a vital factor in our daily lives, especially in regard to the flow and sharing of information.

The organization of this article is structured as follows: introduction (section 1), literature review where the main concepts involved (section 2), methodological aspects used (section 3), case study (section 4), analysis of Research (section 5) and suggestions for future studies.

2. THEORY

The fourth Industrial Revolution was launched in Germany under the concept of "Industry 4.0" in 2011 at a fair in Hannover called Hannover Fair, where it was mentioned how organizations and their global chain will be revolutionized by the arrival of the new Technological concepts that tend to turn industries into smart factories. This call of the fourth industrial revolution will cause a complete integration between virtuality and physical manufacturing systems to be created in global terms that will flexibly cooperate with each other (SCHWAB, 2016). Figure 1 shows the

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evolution of industry according to its start date and the initial milestone of each revolution.

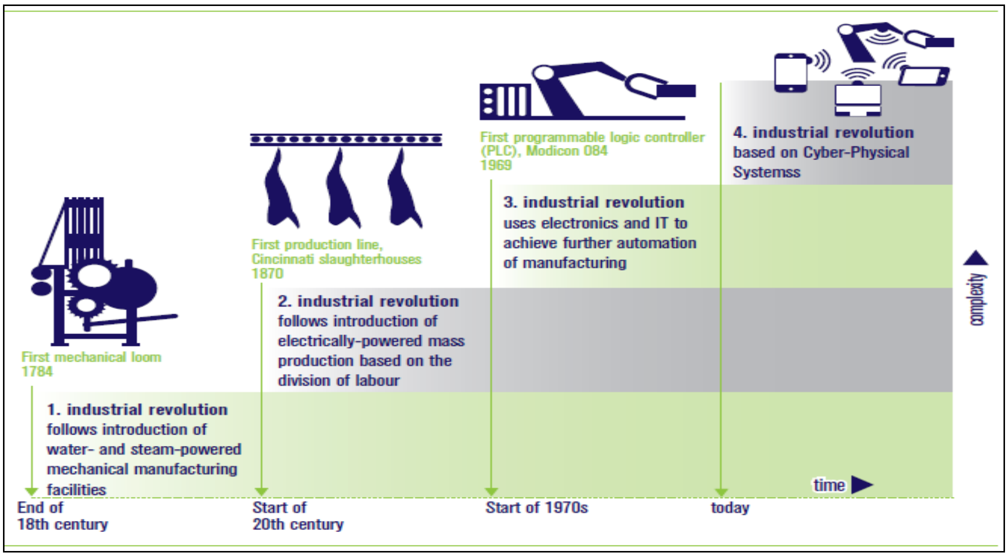

Figure 1: The four stages of the industrial revolution.
Source: KAGERMANN et al (2013)

The fundamental approach of I.4.0 is using the cyber-physical system to provide communication and intelligence for artificial systems, technical systems called "smart systems" or intelligent systems. These intelligent systems can be understood as a consequent technology successor to mechatronic and automated systems. The main feature is the integration of cyber-physical systems to allow inter-system communication and the operation of the automatically controlled system (ANDERL, 2014).

The development of I.4.0 has a substantial influence on the processing industry. One of the aspects of this development is based on the concept of Smart Factories, or intelligent factories, intelligent products and intelligent services embedded in the Internet of Things (IoT) and also services known as Internet Industrial (KARGEMNN, et al 2015).

The future "Industry 4.0" project supports mass customization of production with flexibility and integration of customers and business suppliers into value creation processes. Due to market volatility, flexible production will be supported to respond in a timely manner to a permanent change in requirements, in order to meet all demands (BMBF, 2014). According to Manhart (2015), the keyword "Industry 4.0" means a development that fundamentally changes the traditional industries.

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As mentioned by Shafiq et al. (2015), I.4.0 can be defined as the combination of intelligent machines, processes, production and systems that form an interconnected network of high sophistication, which emphasizes the idea of linking and digitizing manufacturing units in a given economy, tending to virtualize the real world into a large network of centralized information system. I.4.0 will involve the technical integration of CPS (Cyber-Phisical-Production-System) in production and logistics and the use of IoT in industrial processes that were previously not so widely applied (KAGERMANN et al, 2013).

According to Koch et al (2015), I.4.0 goes beyond the physical limits of the company, bringing control over all the entire value chain of a product's life cycle, which is focused on the customization needs of increasingly demanding customers, developing new business models worldwide.

I.4.0 can still be defined as an abstract concept that will increasingly integrate closely the physical world with the virtual world (WAN, et al, 2015), or, as Erol et al. Spreads a vision in which recent developments in information technology are expected to allow entirely new forms of cooperative and production engineering, where the key idea is that products and machines - driven by real-time data, embedded software and the internet - are Organized as autonomous agents within a widespread and agile network of value creation.

The German Federal Minister for the Economy, Gabriel (2015), mentioned during the International Fair of German Industry in Hannover (Germany), 5 topics that are classified for the implementation of I.4.0:

a) Industrial Policy: Development of new business models, based on traditional value chains;

b) Employment Policy: Development of highly qualified jobs;

c) Data Security: Active protection of confidential data against unauthorized access;

d) Medium-sized enterprise policy: Innovation action by medium-sized companies;

e) Regulation: Creation of reference architectures and application examples in order to achieve competitive advantages.

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As mentioned by Kagermann et al. (2013), the development of I.4.0 will only be achieved if the leadership relationship between supplier and customer (market) is coordinated in order to guarantee the benefits for both parties. However, this supply chain approach must be referred to as a dual strategy. Strategies incorporate three characteristics:

- Development of intercompany value chain and integration through horizontal networks;
- Digital end-to-end engineering by the chain of values complete form between both sides, product and production system;
- Development, deployment and vertical integration of a flexible and reconfigurable manufacturing system;

Figure 2 shows the horizontal integration that seeks to provide answers to the questions of cooperation between business strategies, new values of communication networks and new sustainable models through a cyber-physical network. In Figure 3, it seeks the representation of vertical integration through flexible and reconfigurable advanced manufacturing systems.

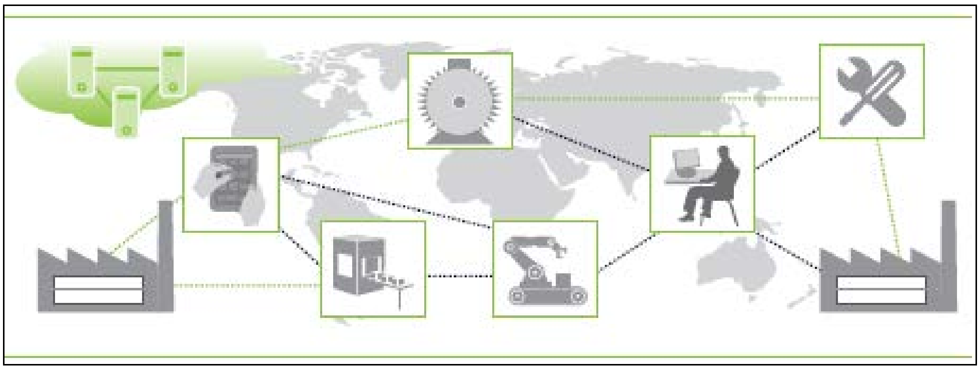

Figure 2: Horizontal integration through network of values.
Source: KAGERMANN et al (2013)

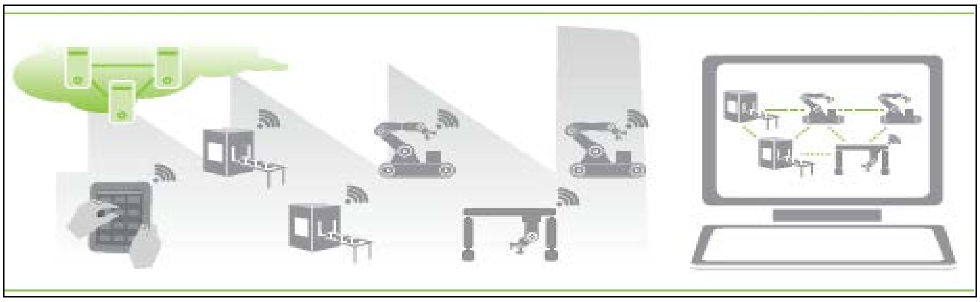

Figure 3: Vertical integration and network of manufacturing systems.
Source: KAGERMANN et al (2013)

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On the other hand, the end-to-end system must be analyzed in a more complete way, taking into account the whole chain of values seeking to foster the digital integration of process engineering so that the real world and the virtual world are integrated throughout Value chain (KAGERMANN, et al, 2013).

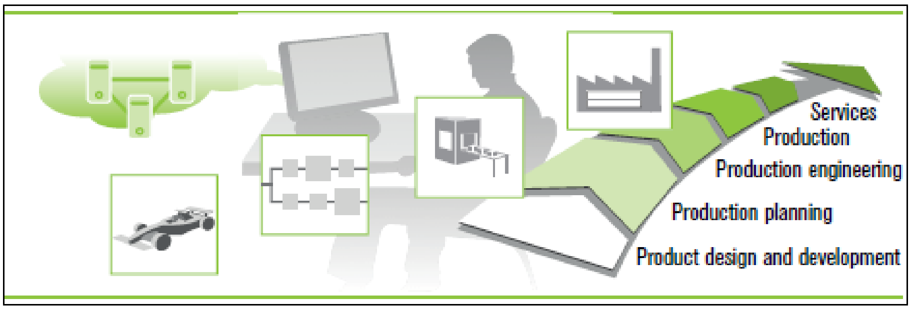

Figure 4: End-to-end engineering across the value chain.
Source: KAGERMANN et al (2013)

As will be shown in Figure 5, end-to-end engineering from the macro viewpoint is the connection between stakeholders, products, and equipment throughout the life cycle of a product, from the raw material acquisition phase to the end of product life.

This life cycle consists of the phase of raw material acquisition, manufacturing (product development and production), use and service, end of life (containing reuse, recycling, recovery and disposal), as well as transport between all phases (STOCK; SELIGER, 2016).

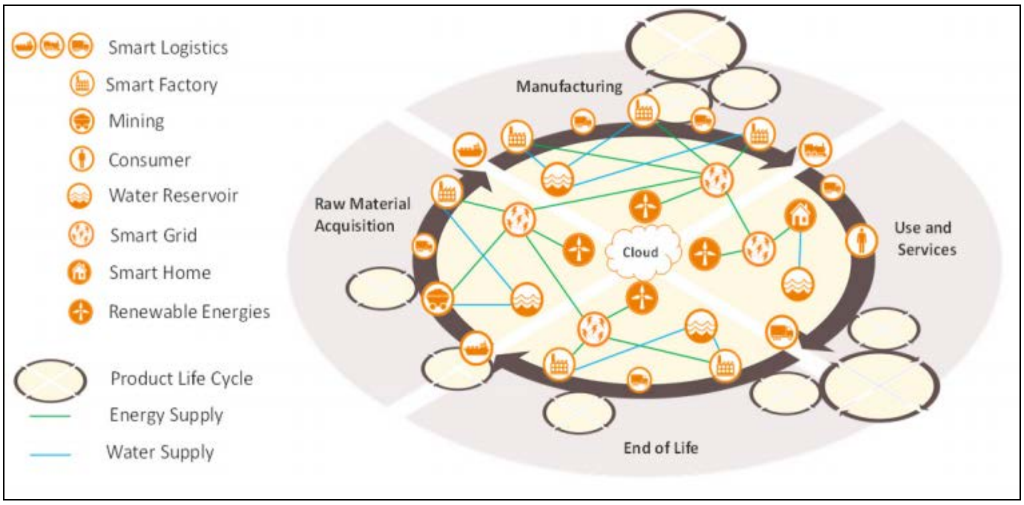

Figure 5: Industry 4.0 macro perspective.
Source: STOCK and SELIGER (2016)

According to figure 6, the micro perspective of industry 4.0 covers mainly horizontal integration as well as vertical integration within smart factories, but is also part of the end-to-end engineering (STOCK; SELIGER, 2016).

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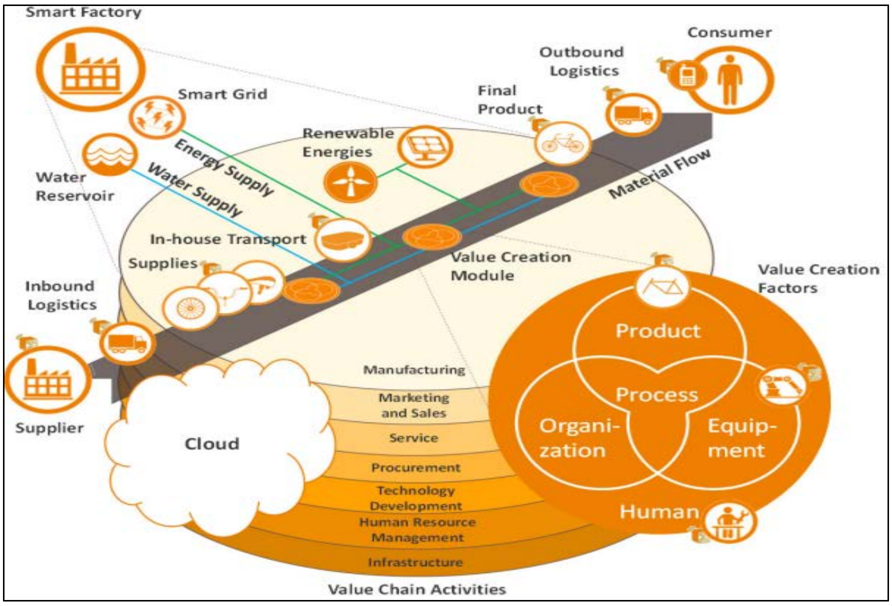

Figure 6: Industry 4.0 micro perspective.
Source: STOCK and SELIGER (2016)

One important technology used in the I.4.0 concept is B2B, or Business-to-Business (B2B). This relationship generally refers to business transactions between two companies and the exchange of both products and services, including the sale of raw material on one side and confirmed by the other. The primary economic advantage of B2B commerce, which I.4.0 is growing, is:

- Simplify the acquisition process by adding efficiency to this aspect of the overall production process (ALBRECHT et al, 2005);
- Reduction in the cost of acquisition before the transaction, reducing the research costs associated with acquisition entries and increasing the easiness of pricing (KANDAMPULLY, 2003);
- Reduction of costs associated with the monitoring of contractual and product performance or the provision of services (KAPLAN; SAWHNEY, 2000);

BI or business intelligence refers to the technologies, systems, techniques, methodologies, practices and critical data analysis applications of a given business to help companies better see their business and the market in which they are inserted and reduce the time taken to make Decision (CHEN et al., 2012). Based on BI, smarts factories increase the transparency of information by giving autonomy to the manufacturing company (RADZIWON, et al., 2014).

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3. METHODOLOGY AND RESEARCH METHOD

Regarding the development of the research in its methodology, the study is characterized as an applied research, with the form of a qualitative approach, with the descriptive objective, with a bibliographical and documentary approach followed by a case study.

An approach to the problem is an applied research, where it aims to generate knowledge for practical application directed to the solution of specific problems, involving local truths and interests (ROESCH, 2006).

The qualitative approach that is based on the interpretation of phenomena and the attribution of meanings, being that the researcher is considered a key instrument and the natural environment, the direct source for data collection (MARTINS, 2010).

Taking as a bibliographical and documentary approach, which requires theoretical and environmental knowledge, to identify the causes and effects and to describe the phenomenon based on the analyzed frame.

As a final technical procedure of the methodology, the case study was used, and this was done in the multinational company of German origin in the industrial segment of instrumentation and control manufacturing. It is worth emphasizing that the propositions presented by the basic theory justify the use of a single case study, insofar as these theories can be confirmed, challenged or extended in the face of revealed truth, thus representing a significant test of theory, according to The orientation of Yin (2010).

The steps of the research method that served as the basis for this study were adapted from Yin (2010), which is shown in Figure 7 and described below.

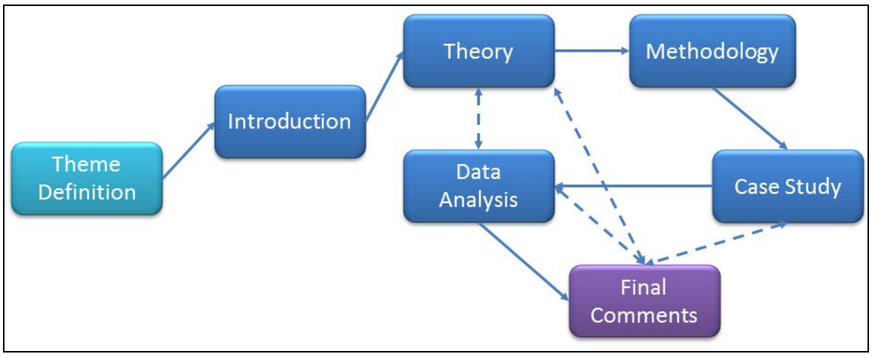

Figure 7: Steps of the search method.
Source: Yin (2010)

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The company expressed great concern about the dissemination of all content for exclusive use, but it helped in any way to collect the data necessary for the preparation of the work as well as made available all the necessary material for consultation.

To obtain data from the case study, interviews, research protocols, publications published internally in the organization and files available for consultation in the company's own network were used as data collection. Regarding the interviews, the interviewees were practically all directly involved in the development of the project, from the project manager to technicians and engineers responsible for the technical part to the employees on the factory floor, in order to guarantee A greater efficiency in the veracity of the data acquired in the interviews.

As for internal publications, the company has a newspaper of internal disclosure that, although not available for external disclosure, was of great value in the elaboration of the work. The same occurred with the files available for queries located in the company's servers that, although it was not allowed to divulge the data found in the files, where these data were of great importance in the survey of the requirements established in the work in question.

Most of the research protocols used in this work was taken advantage of the forms already existing in the company, so they could not be disclosed, however the author assumes responsibility for the veracity of the data.

The forms provided by the company were only two: "Planning hour x hour" (shown in chapter 4.4) and the "Time Observation Form", used to measure the times of different tasks performed, which will be demonstrated in the following figure.

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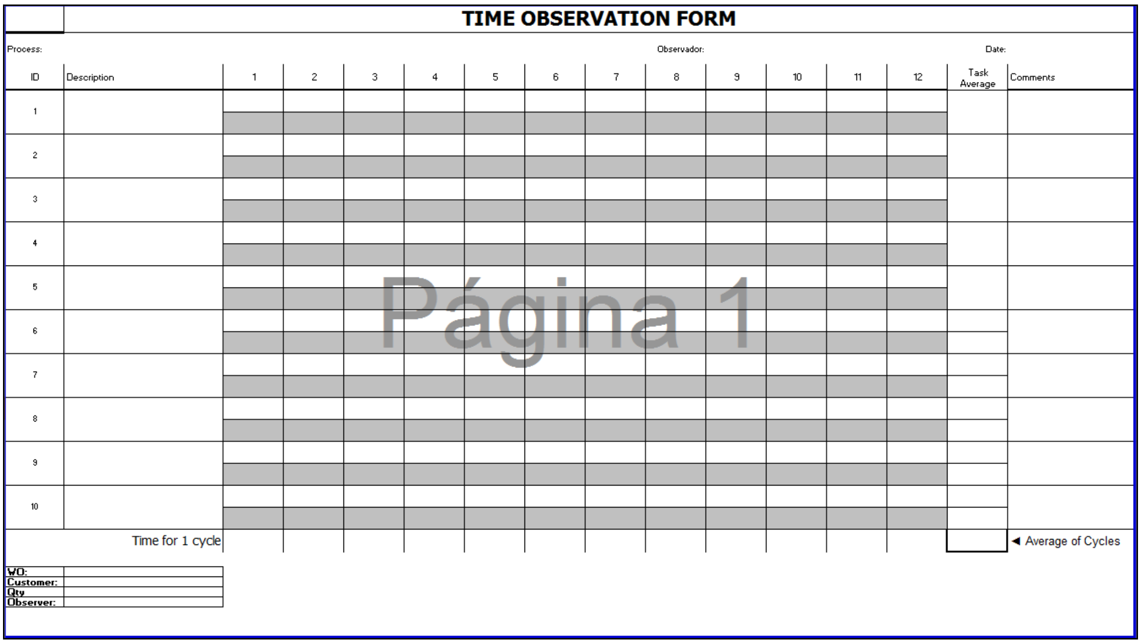

Figure 8: Sample of the time observation form

The following table shows the measurement methods (Research protocols) and also the instrument of data collection, in order to provide a better understanding of the reader.

Table 1: Table of measuring methods, criteria's e data collection

Tech	Data	Criteria description	Measuring Method / Research Protocol	Data Collection Instrument
Information Management	ERP Deployment	Reduction of time in the process of importing parts and pieces.	Planning KPI's	Receiving goods form (Private Company Form)
		Reduction of labor force in carrying out the import process.	HR/Planning KPI's	Employee per Cost Center Form (Private Company Form)
		Reduction of the technical workforce in the accomplishment of the task of creation of lists of materials and manufacturing scripts + reduction of the time of response for beginning of manufacture.	Engineering/HR KPI's	Time Observation Form + Employee per Cost Center Form (Private Company Forms)
	Business Inteligence	Reduction of labor in the survey and collection of data + reduction of data evaluation time	HR/Planning KPI's	Employee per Cost Center Form (Private Company Form)
Information Management	ERP Deployment	Reduction of the technical workforce in the task of collecting and recording data.	Number of employee	Employee per Cost Center Form (Private Company Form)
		Increased productivity due to time / hour monitoring.	Production KPI's	Manual time measuring and registering on the Time Observation Form
		Reduced planning and sequencing workforce + reduced capacity planning time.	HR/Production KPI's	Manual time measuring and registering on the form + Employee per Cost Center Form (Private Company Form)

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	Structural	Increased employee commitment and, as a consequence, reduction of absenteeism.	HR/Planning KPI's	Absenteism Form (Private Company Form)
Information Management	Voltage Control / Input Current.	Improved consumption forecasting for decision making.	Maintenance KPI's	Internal Surveys Form (Internal Company form)
		Reduction of maintenance expenses and reduction of preventive maintenance time due to monitoring.	Maintenance KPI's	MTBF KPI (Private Internal Form)
		Reduction of energy consumption.	External Power Supply Company	Invoice/Bill (Private Costs)
	Temperature Control	Reduction of production stops.	Production KPI's	Hour x Hour Form
		Reduction of "ppm" rework and scrap (quality improvement).	Quality Management System KPI	PPM form (Private Company Form)
		Increased availability of the company's server without variations.	IT KPI's	Server Availability Form (Private Company Form)
	Pressure Control	Reduction of production stops.	Production KPI's	Hour x Hour Form
		Reduction of "ppm" rework and scrap (quality improvement)	Quality Management System KPI	Scrap/Rework form (Private Company Form)
		Increased availability of the company's compressed air without variations.	Maintenance KPI's	MTBF KPI (Private Internal Form)
	Pressure Control	Reduced maintenance costs and leak detection in real time reducing waste.	Maintenance KPI's	Gases Consumption Form (Private Internal Form)
		Reduction of production stops.	Production KPI's	Hour x Hour Form
	Availability control	Reduction of production stops.	Production KPI's	Hour x Hour Form
		Assistance in decision-making.	Surveys	Internal Surveys Form (Internal Company form)
		Elimination of labor of collection and presentation of the indicators.	HR KPI's	Employee per Cost Center Form (Private Company Form)
		Reduced corrective maintenance costs through real-time monitoring of more equipment.	Maintenance KPI's	MTBF KPI (Private Internal Form)
		Reduced corrective maintenance and increased preventive maintenance time.	Maintenance KPI's	MTBF KPI (Private Internal Form)
		Greater efficiency in maintenance planning.	HR/Maintanace KPI's	Employee per Cost Center Form (Private Company Form)
		Greater efficiency in standalone solutions.	HR/Maintanace KPI's	Employee per Cost Center Form (Private Company Form)
		Assistance in decision-making.	Surveys	Internal Surveys Form (Internal Company form)

The following figure shows the road map of the study case research in order present to the reader a better understanding of the paper.

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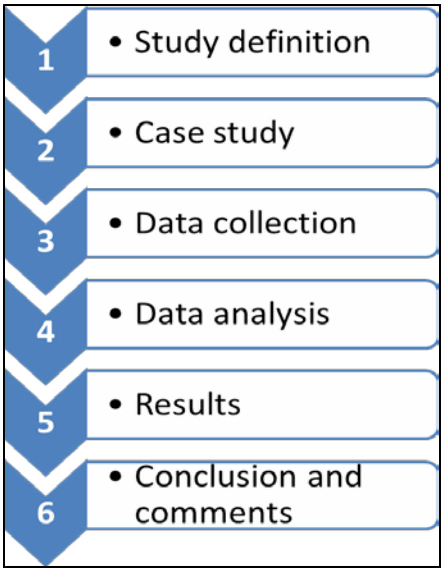

Figure 9: Research roadmap

4. CASE STUDY

4.1. Company profile

For this case study, the company analyzed is a large German multinational, with a global presence in more than 40 countries, located in the interior of the State of São Paulo - Brazil, characterized by the production of measurement and monitoring instruments for industrial processes, for the most diverse sectors, such as: sugar and alcohol, chemical and petrochemical, oil and gas, and equipment manufacturers in general. These process measurement and monitoring instruments are mainly for the purpose of monitoring quantities related to pressure, temperature, level and flow.

The unit studied in the national market (85%) and international (15%), currently representing an annual turnover of approximately R $ 150 million (2015) and, according to the aforementioned quantities, the company estimates its participation in the national market (Market-Share) in 60% for pressure measurement, 17% for temperature measurement, 9% for level measurement and 3.5% for flow measurement.

The company currently has several implemented technologies that are part of the technological innovation project aiming to be more competitive through the so-called I.4.0 technologies. The technologies currently available will be divided into 3 categories: information management, maintenance management and production management, as shown in Figure 10.

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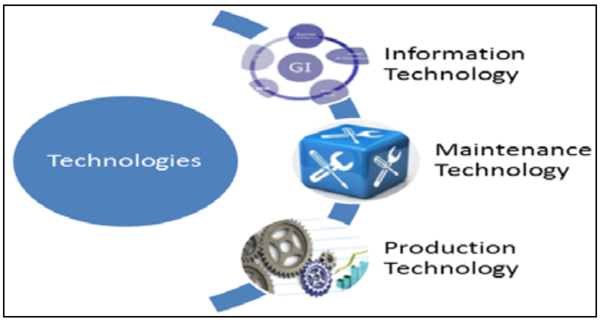

Figure 10: Division of available technologies.

4.2. Information management

This section called information management was thus established taking into account the main available technologies related to the management of administrative control. The use of control and management systems has meant that several tasks have become obsolete or the handling time has been reduced. With the implementation of ERP (Enterprise Resource Planning), the process of importing parts and pieces of products has become more agile, reducing time that does not add value in document issuance, avoiding error messages.

From this point on, it was possible to use B2B between the company studied and its main suppliers, where the need to buy / import is automatically generated by the ERP soon after the implementation of the order by the sales department and the simultaneous receipt of the order of the given by the supplier, already with agreed prices and deadlines, without the interference of any operator. Figure 11 shows a representation of the B2B system used by the company, where the operator does not participate directly in the importation of the item, but only receives confirmation from the supplier.

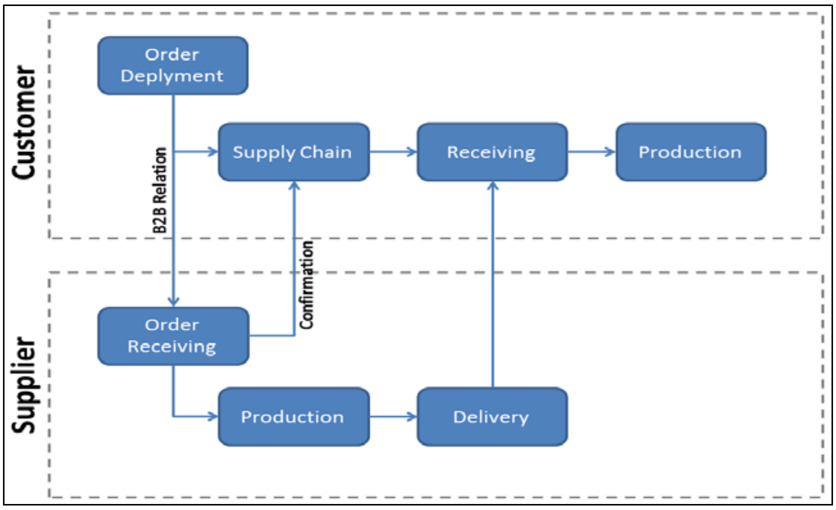

Figure 11: Macro representation of the B2B system in the company studied.

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The implementation of the new system facilitated the work interface between several areas, being one of the most expressive the performance of a product configurator directly in the ERP system. Previously, the process of implementing a sales order for a new item would go from the sales department to the engineering department to register the item, and then return to the sales department to carry out the order implementation and then proceed to the logistics process and productive.

After the new system, it is possible to automatically generate the item registration (automatically creating the material list and the manufacturing schedule according to previously established parameters), automatically calculating the delivery time according to the availability of the components and availability of machine load, thus eliminating engineering department work for standard items.

The system automatically recognizes standard items (creating lists and scripts) and for non-standard items, the system automatically creates an alarm that changes the whole information chain of this item, changing its delivery time and generating a special need for item configuration by engineering.

For customers with special contracts with the company, the system has a logic of autonomous decision making, where, after the purchase order is implemented (and can be carried out by the customer via remote access), the customer already receives a return automatically from the best date of delivery and, in case of possible failures in the process, the customer will be automatically informed about the delay and the new deadline. In Figure 12, the process eliminated from the engineering department by the new system is presented.

Still, in terms of information management, the company adopted the use of a real-time, fully customizable and programmable BI data extraction system (Business Intelligence) directly from ERP, where it allows parameterizations of graphs and reports, unavailable in the ERP. Through this customization, the whole management team of the company can make the decision more quickly through the data and information gathered by the information system, eliminating a long export analysis and filtering the data exported by the ERP, reducing the hand of applied task. All data extracted from the BI is fed in real time, and the update time is negligible.

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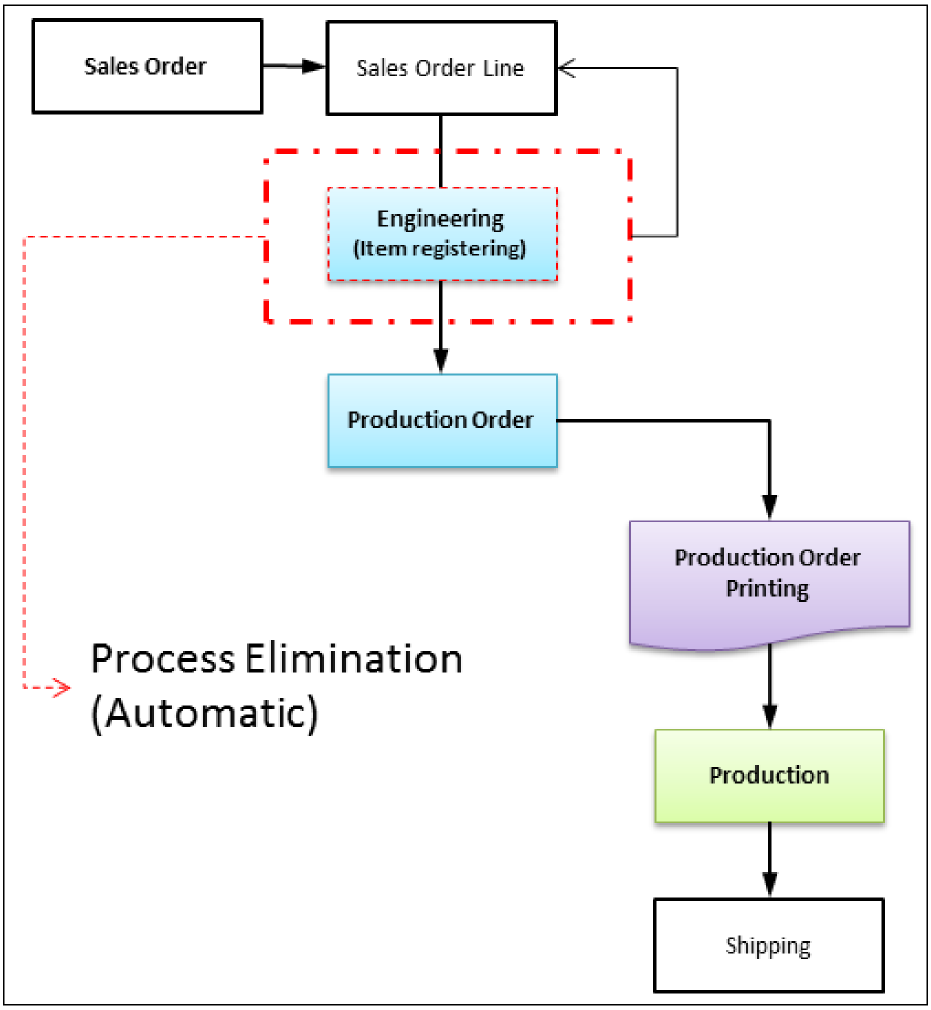

Figure 12: Elimination of the registration process of standard items.

4.3. Maintenance management

As the need for continuous improvement and reduction of waste is increasingly troublesome, it is necessary not only to control all the variables of the manufacturing process, but also to control the industrial variables considered as background, such as energy consumption, water consumption, voltage variation, and so on.

Due to the need for this control, a supervisory system was created, based on the Arduino platform, for a remote management of the largest possible number of data. The data is controlled remotely through the company's server, and its data is monitored and recorded in real time, which provides a better response time in case of failure.

The variables monitored through the supervisory system will be listed and commented dynamically, as can be seen in Table 2.

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Table2: Table of management control of maintenance through the supervisory system.

Data	Comments
Voltage Control / Input Current.	- Real-time verification of energy consumption as well as consumption forecast.
	- Verification of power surges aiding in the planning of use of high voltage equipment.
	- Checking for voltage leaks, aiding in the waste of energy.
Temperature Control	- Temperature control of all production processes (where temperature is a controllable factor), aiding in process stability, ensuring product quality.
	- Reduction of scrap cost by controlling process variation.
	- CPD room temperature control, preventing electronic components from being damaged, consequently keeping the plant in perfect working order.
Pressure Control	- Pressure control of all production processes (where pressure is a controllable factor), aiding in process stability, ensuring product quality.
	- Reduction of scrap cost by controlling process variation.
	- Control of the pressure of the compressed air network avoiding that there are falls or variations in the network, consequently keeping the plant in perfect operation.
Level Control	- Level control of the main water tank, cistern and firebox, meeting current standards and keeping the plant in operation.
	- Glycerine level control of all production processes (where glycerin is a controllable factor), assisting in process stability, ensuring product quality.
Availability control and data management	- Measurement of the availability of machines and equipment, keeping the plant in perfect working order.
	- Consultation and records of all occurrences, assisting in the history of the equipment, assisting in the decision making and possible substitution.
	- Presentation of the indicators of maintenance in real time, with data collected by the supervisory system.
	- Reduced maintenance costs through more precise monitoring.
	- Reduction in response time in case of corrective maintenance.
	- Improvement in preventive maintenance planning.
	- Generation of alarms for all the critical variables of the process, however the supervisory system is able to make the decision autonomously to solve the problem.
	- Remote intervention through the control room.

The control of these variables is done through the supervisory system, where it has a simple interface, easy to understand and easy to comprehend, in order to facilitate the analysis of the operators, as shown in figure 13.

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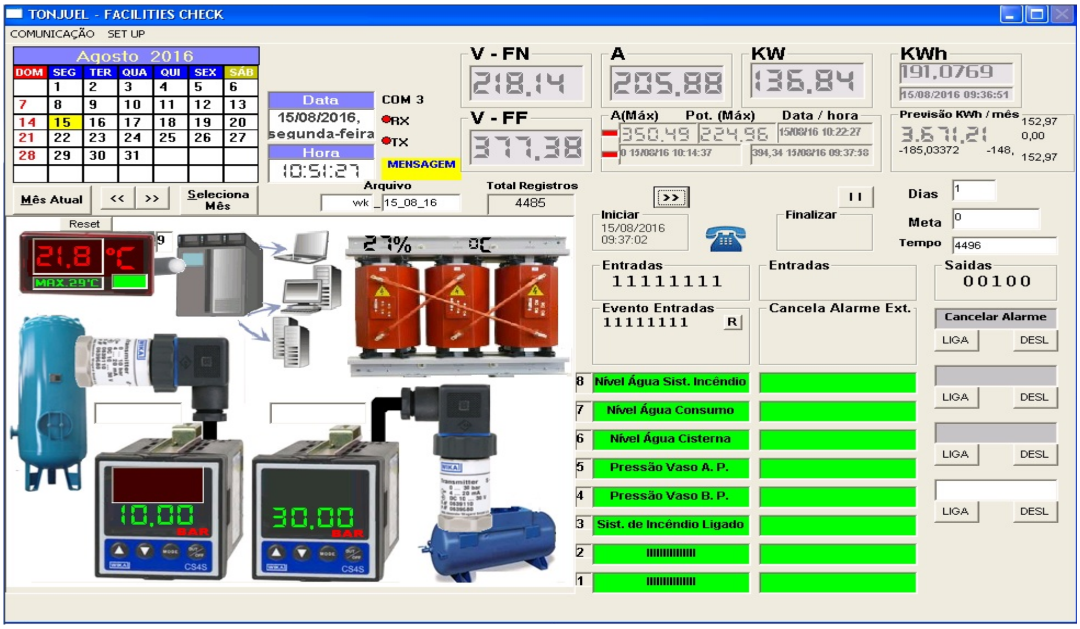

Figure 13: Supervisory system interface.

Through preprogrammed alarms, the supervisory system is able to make decisions autonomously, sending signals to the receiving equipment and thus making decisions of automatic control or communication to the person in charge via telephone connection or SMS type message.

4.4. Production management

In this section the principles of the Lean Manufacturing philosophy will be disregarded, since its concepts are already intrinsic in data management, as well as in the management of production lines.

Production management is done remotely and with updates in real time. The data are collected from the management system (ERP) and added to a system developed internally by the company, which compiles, checks and filters all information, performing production calculations and monitoring production time.

In order to make a better follow-up, visual production management displays were installed directly on the production lines where their updating is automatic (through the management system), so that all employees are able to check the current status of the line Of production, verifying that what is being produced is in accordance with what was planned and also making all employees committed to achieving the goal on an hourly basis.

This system controls various production variables, such as: productivity, hours worked control, production targets, waste control, autonomous maintenance, safety

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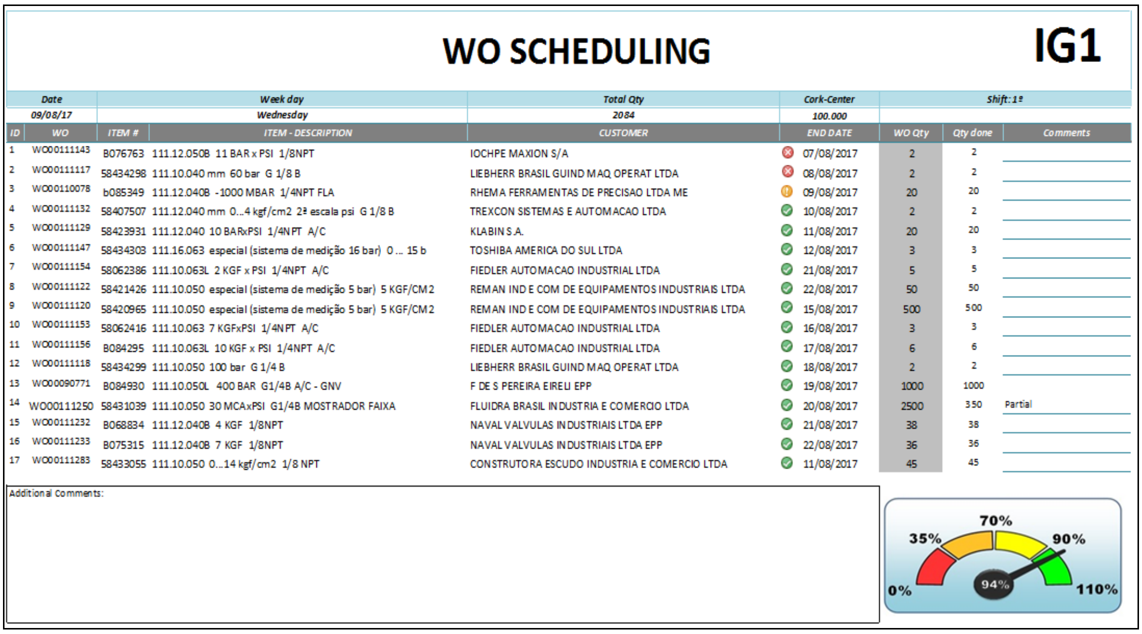
and production line suggestions, and through the displays the main indicators are presented and Remotely updated, as is the case of Figures 14 and 15 below.

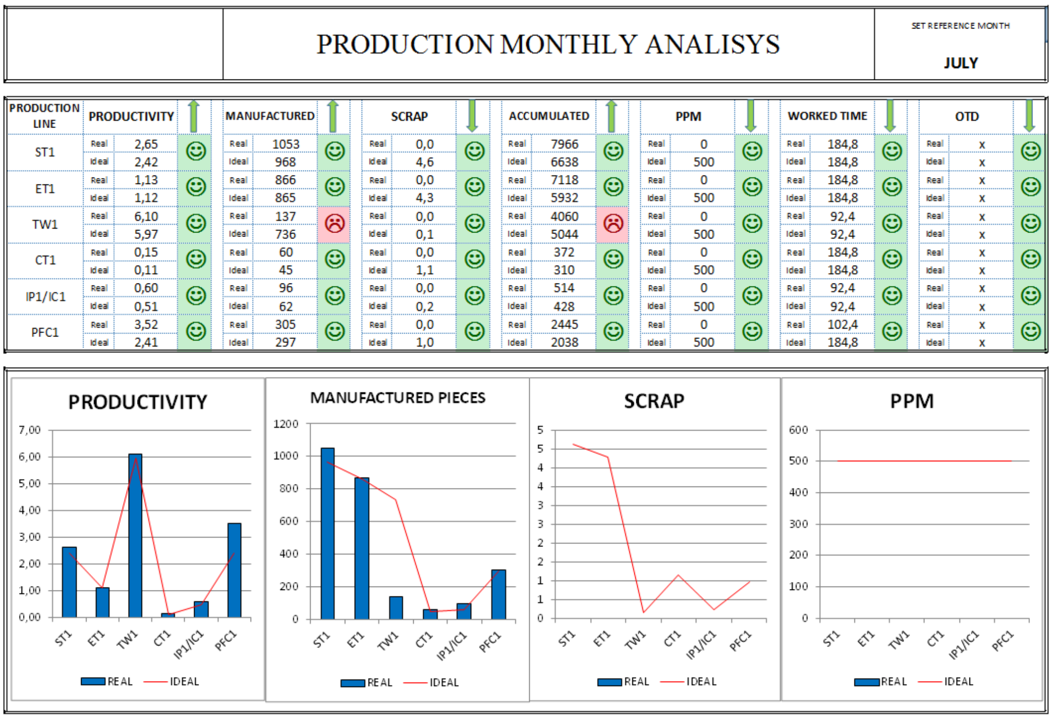


WO SCHEDULING **IG1**

Date	Week day	Total Qty	Cork-Center	Shift: 1º
09/08/17	Wednesday	2084	100.000	

ID	WO	ITEM #	ITEM - DESCRIPTION	CUSTOMER	END DATE	WO Qty	Qty done	Comments
1	WO00111143	B076763	111.12.050B 11 BAR x PSI 1/8NPT	IOCHPE MAXION S/A	07/08/2017	2	2	
2	WO00111117	58434298	111.10.040 mm 60 bar G 1/8 B	LIEBHERR BRASIL GUIND MAQ OPERAT LTDA	08/08/2017	2	2	
3	WO00110078	b085349	111.12.040B -1000 MBAR 1/4NPT FLA	RHEMA FERRAMENTAS DE PRECISAO LTDA ME	09/08/2017	20	20	
4	WO00111132	58407507	111.12.040 mm 0...4 kgf/cm2 2ª escala psi G 1/8 B	TREXCON SISTEMAS E AUTOMACAO LTDA	10/08/2017	2	2	
5	WO00111129	58423931	111.12.040 10 BARxPSI 1/4NPT A/C	KLABIN S.A.	11/08/2017	20	20	
6	WO00111147	58434303	111.16.063 especial (sistema de medição 16 bar) 0 ... 15 b	TOSHIBA AMERICA DO SUL LTDA	12/08/2017	3	3	
7	WO00111154	58062386	111.10.063L 2 KGF x PSI 1/4NPT A/C	FIEDLER AUTOMACAO INDUSTRIAL LTDA	21/08/2017	5	5	
8	WO00111122	58421426	111.10.050 especial (sistema de medição 5 bar) 5 KGF/CM2	REMAN IND E COM DE EQUIPAMENTOS INDUSTRIAIS LTDA	22/08/2017	50	50	
9	WO00111120	58420965	111.10.050 especial (sistema de medição 5 bar) 5 KGF/CM2	REMAN IND E COM DE EQUIPAMENTOS INDUSTRIAIS LTDA	15/08/2017	500	500	
10	WO00111153	58062416	111.10.063 7 KGFxPSI 1/4NPT A/C	FIEDLER AUTOMACAO INDUSTRIAL LTDA	16/08/2017	3	3	
11	WO00111156	B084295	111.10.063L 10 KGF x PSI 1/4NPT A/C	FIEDLER AUTOMACAO INDUSTRIAL LTDA	17/08/2017	6	6	
12	WO00111118	58434299	111.10.050 100 bar G 1/4 B	LIEBHERR BRASIL GUIND MAQ OPERAT LTDA	18/08/2017	2	2	
13	WO00090771	B084930	111.10.050L 400 BAR G1/4B A/C - GNV	F DE S PEREIRA EIRELI EPP	19/08/2017	1000	1000	
14	WO00111250	58431039	111.10.050 30 MCAxPSI G1/4B MOSTRADOR FAIXA	FLUIDRA BRASIL INDUSTRIA E COMERCIO LTDA	20/08/2017	2500	350	Partial
15	WO00111232	B068834	111.12.040B 4 KGF 1/8NPT	NAVAL VALVULAS INDUSTRIAIS LTDA EPP	21/08/2017	38	38	
16	WO00111233	B075315	111.12.040B 7 KGF 1/8NPT	NAVAL VALVULAS INDUSTRIAIS LTDA EPP	22/08/2017	36	36	
17	WO00111283	58433055	111.10.050 0...14 kgf/cm2 1/8 NPT	CONSTRUTORA ESCUDO INDUSTRIA E COMERCIO LTDA	11/08/2017	45	45	

Figure 14: Planning hour x hour



PRODUCTION MONTHLY ANALISYS

SET REFERENCE MONTH: JULY

PRODUCTION LINE		PRODUCTIVITY	MANUFACTURED	SCRAP	ACCUMULATED	PPM	WORKED TIME	OTD
ST1	Real	2,65	1053	0,0	7966	0	184,8	x
	Ideal	2,42	968	4,6	6638	500	184,8	x
ET1	Real	1,13	866	0,0	7118	0	184,8	x
	Ideal	1,12	865	4,3	5932	500	184,8	x
TW1	Real	6,10	137	0,0	4060	0	92,4	x
	Ideal	5,97	736	0,1	5044	500	92,4	x
CT1	Real	0,15	60	0,0	372	0	184,8	x
	Ideal	0,11	45	1,1	310	500	184,8	x
IP1/IC1	Real	0,60	96	0,0	514	0	92,4	x
	Ideal	0,51	62	0,2	428	500	92,4	x
PFC1	Real	3,52	305	0,0	2445	0	102,4	x
	Ideal	2,41	297	1,0	2038	500	184,8	x

Figure 15: Monthly analysis model of production lines.

The preparation of the "hour by hour" planning is carried out directly by the PCP (production planning and control) and, if manufacturing does not meet the quantity of planned parts, the graph automatically indicates and alarms are generated for the entire industrial management body to action is taken promptly. The

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system is also able to automatically recognize variation in the production time of certain models and the system itself takes an action independently of sequencing aiming at the final result.

5. DATA ANALYSIS

After the implementation of some of the concepts adopted by the I.4.0 call, several analyzes were carried out to verify the effectiveness of the use of the above mentioned concepts. An indicator called "Index of Economy" was created that corresponds to a percentage value of how much the company saved in relation to the previous process, without the use of the techniques / tools mentioned in the study.

This percentage value took into account 3 primary resources: financial (considering cost reduction or reduction of salary directly linked to activity), time (considering the reduction of the time used in the activity based on the time before the current one) and accuracy of information (Considering that the accuracy of the information favors the company's strategy, so it will be considered as a 1% gain). The values are represented in percentage due to a confidentiality policy of the company, where it does not allow the disclosure of monetary values. All tables are analyzed according to the same denominators (financial, time and accuracy of information).

It will be shown below, tables relating the employment gains of the I4.0 concepts, being composed of 3 tables divided in the same groups mentioned above: Table 3 - representing gains related to information management, Table 4 - representing the gains related to production management, and table 5 - representing gains related to maintenance management. At this point the percentage indices are evaluated individually, being compared between the current stage and the previous stage.

Table 3 shows the gains of the new technologies in the area of information management, based on "Information Technology" and control, management and industrial monitoring systems.

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Table 3: Table of percentage gains of information management.

Data	Item	Gains with new Technologies	$	Time	Precision	Total
1. ERP Deployment	1.1	Reduction of time in the process of importing parts and pieces.	0,0%	14,5%	1,0%	15,5%
	1.2	Reduction of labor force in carrying out the import process.	33,3%	0,0%	1,0%	34,3%
	1.3	Reduction of the technical workforce in the accomplishment of the task of creation of lists of materials and manufacturing scripts + reduction of the time of response for beginning of manufacture.	20,0%	14,2%	1,0%	35,2%
2. Business Inteligence	2.1	Reduction of labor in the survey and collection of data + reduction of data evaluation time + aid in decision making.	16,3%	45,0%	1,0%	62,3%
					Economy Index	36,8%

Table 4 shows the gains of the new technologies in the area of production management, based on the control and monitoring technologies of the manufacturing process directly on the production lines.

Table 4: Table of percentage gains of production management.

Data	Item	Comments	Gains with new Technologies	$	Time	Precision	Total
1. ERP Deployment	1.1	- Real time recording and data collection.	Reduction of the technical workforce in the task of collecting and recording data.	15,5%	45,0%	1,0%	61,5%
	1.2	- Real time monitoring.	Increased productivity due to time / hour monitoring.	3,2%	0,0%	1,0%	4,2%
	1.3	- Planning and sequencing of production autonomously.	Reduced planning and sequencing workforce + reduced capacity planning time.	6,0%	15,0%	1,0%	22,0%
2. Structural	2.1	- Installation of displays (TV's) on production lines.	Increased employee commitment and, as a consequence, reduction of absenteeism.	0,5%	0,0%	1,0%	1,5%
						Economy Index	22,3%

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Table 5 shows the gains of the new technologies in the area of maintenance management, based on the control and monitoring technologies of production processes, as well as control and monitoring of variable costs of the company as a whole.

Table 5: Table of percentage gains of maintenance management.

Data	Item	Gains with new Technologies	$	Time	Precision	Total
1. Voltage Control / Input Current.	1.1	Improved consumption forecasting for decision making.	0,0%	0,0%	1,0%	1,0%
	1.2	Reduction of maintenance expenses and reduction of preventive maintenance time due to monitoring.	5,2%	5,0%	1,0%	11,2%
	1.3	Reduction of energy consumption.	11,3%	0,0%	1,0%	12,3%
2. Temperature Control	2.1	Reduction of production stops.	4,4%	3,0%	1,0%	8,4%
	2.2	Reduction of "ppm" rework and scrap (quality improvement).	0,5%	0,0%	1,0%	1,5%
	2.3	Increased availability of the company's server without variations.	0,2%	2,3%	1,0%	3,5%
3. Pressure Control	3.1	Reduction of production stops.	4,4%	3,0%	1,0%	8,4%
	3.2	Reduction of "ppm" rework and scrap (quality improvement)	0,5%	0,0%	1,0%	1,5%
	3.3	Increased availability of the company's compressed air without variations.	6,7%	3,0%	1,0%	10,7%
4. Pressure Control	4.1	Reduced maintenance costs and leak detection in real time reducing waste.	11,8%	1,0%	1,0%	13,8%
	4.2	Reduction of production stops.	1,0%	0,2%	1,0%	2,2%
5. Availability control	5.1	Reduction of production stops.	5,6%	2,0%	1,0%	8,6%
	5.2	Assistance in decision-making.	0,0%	0,0%	1,0%	1,0%
	5.3	Elimination of labor of collection and presentation of the indicators.	2,0%	1,0%	1,0%	4,0%
	5.4	Reduced corrective maintenance costs through real-time monitoring of	21,7%	0,0%	1,0%	22,7%

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	more equipment.				
5.5	Reduced corrective maintenance and increased preventive maintenance time.	8,8%	12,0%	1,0%	21,8%
5.6	Greater efficiency in maintenance planning.	0,0%	0,0%	1,0%	1,0%
5.7	Greater efficiency in standalone solutions.	9,0%	11,2%	1,0%	21,2%
5.8	Assistance in decision-making.	0,0%	0,0%	1,0%	1,0%

Economy Index 8,2%

The three tables above present the gains of the implementation of new technologies in the three different management levels presented in this study, Information Management, Production Management and Maintenance Management. The purpose of these tables is to demonstrate clearly and rapidly the behavior of these technologies and their possible percentage gains, also serving as introductory tables for the final analysis and comments.

6. FINAL COMMENTS

This study aimed to analyze the technologies related to I.4.0 in a German subsidiary located in Brazil, in the area of instrumentation and control, where a case study was used to conduct the study. As a result, it was possible to positively analyze the current technologies used and, as presented, one of its main advantages is clear: the reduction of organizational costs, making the company more competitive against its competition in global terms.

In the above study, it is sometimes possible to observe the reduction of the labor force employed in certain tasks, however it is of great value to mention that the labor force was not totally eliminated, but rather reallocated to perform other tasks, as well as transformed into skilled workforce in IT tasks.

As observed in the presented tables, significant gains in all areas analyzed could be easily noticed, but the percentage values described were treated individually, that is, the analysis made took into account the previous and subsequent costs individually according to each item analyzed, disregarding the impact that each index has on the results of the company as a whole.

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In order to be analyzed in a global way, a calculation of these percentages was made, taking into account how much each improvement (percentage value) would influence the annual financial result of the company. The calculation is based on the financial value saved in relation to the annual billing, serving as a factor of leveling of the different percentages, ie, all the following values are analyzed with the same weight from the financial perspective (however represented in percentage values as criteria of the company studied).

After this calculation, each of the three areas (information management, maintenance management and production management) impacted on a different result of the company's gain, as is already expected. According to Figure 16, the real impact of the gain of each area according to previously established criteria will be demonstrated.

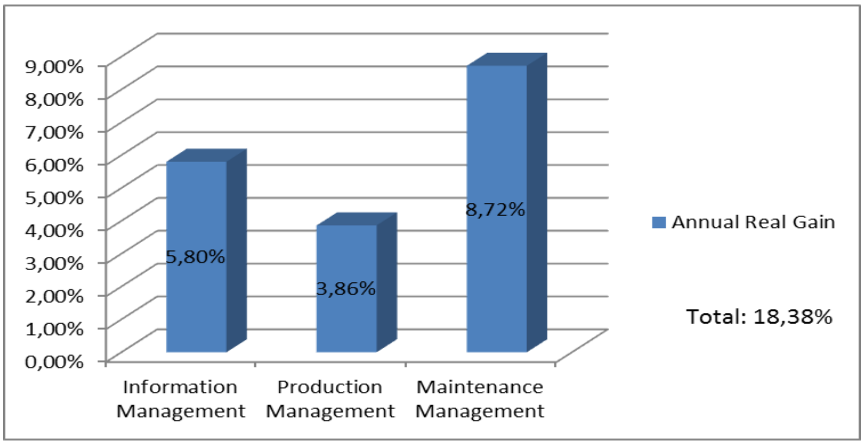

Figure 16: Annual real gain using the available I4.0 technologies.

The author considers that the objectives of the study were successfully achieved, where it was possible to verify the I.4.0 technologies practices to the theory, where the premises are based on connectivity, bigdata and autonomous decisions that were demonstrated in the case study, as well as It was possible to analyze the company's maturity against I.4.0 mainly focused on cost reduction.

It is hoped that this work has contributed to increase understanding of how an industry can fit I.4.0, which is a company that produces capital goods with custom engineering in the area of instrumentation and control, where the lack of a structured technology management is still not as present as in its headquarters located in Germany.

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As a suggestion for future studies, correlating the available technologies in the Company and other competing companies would be an interesting basis to verify the degree of maturity of the Brazilian industry against the concept of I.4.0 in the area of instrumentation and control. Another suggestion would be to correlate the data collected from the subsidiary before the matrix, where it would be interesting to check the difference in the level of maturity between Germany and Brazil.

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