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Industrial Engineering and Operations Management II

XXIV IJCIEOM, Lisbon, Portugal, July 18–20

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Editors

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Preface

Industrial Engineering and Operations Management (IE&OM) are enabling enterprises around the world to adapt and survive in turbulent environments. IE&OM are becoming more and more relevant to overcome complex situations in a digital era, where innovation cycles are increasingly shorter.

As IE&OM are playing a pivotal role, the series of International Joint Conference on Industrial Engineering and Operations Management (IJCIEOM) is offering to researchers the opportunity to share their current research to establish new partnerships and to publish their articles. This joint conference is a result of an agreement between ABEPRO (Associação Brasileira de Engenharia de Produção), ADINGOR (Asociación para el Desarrollo de la Ingeniería de Organización), IISE (Institute of Industrial and Systems Engineers), AIM (European Academy for Industrial Management), and ASEM (American Society for Engineering Management) with the objective of promoting relationships between researchers and practitioners from different branches, and enhancing an interdisciplinary perspective of industrial engineering and management.

The International Joint Conference on Industrial Engineering and Operations Management was the twenty fourth conference in the IJCIEOM series. It was hosted by the Military Academy of Portugal, during 18–20 of July, 2018. It included five relevant topics: Business models and Service science; Education; Logistics, production and product management; Quality and product management; and Operations management.

As the IJCIEOM18 call for papers attracted scientists from all over the world, the conference organizing committee received up to 200 submissions from 20 countries, out of which the scientific committee selected 49 top-quality papers. All the papers were reviewed by at least two scholars from the scientific committee, composed by renowned scientists specialized on the aforementioned topics. This Springer book is the second of two volumes and contains 25 articles. Inside, you can find papers that explore real-life phenomena under the IE&OM scope, thus, providing various perspectives in the fields of: healthcare, social technologies, mathematical programming applications, public transport services, new product development, industry 4.0, occupational safety, quality control, e-services, risk management, supply chain management, governance, and digital operations. All these papers put forward novel approaches and relevant findings that shed new light on IE&OM.

We would like to mention a special thanks to the IJCIEOM referees for their great work in reviewing all the papers and the keynote speakers for their contribution to push this field of science forward.

Amadora, Portugal João Reis
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October 2018

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Performance Measurement System to Continuously Improve a Brazilian Industrial Engineering Program: A Process to ABET Accreditation

Gabriela Lobo Veiga, Edson Pinheiro de Lima, Fernando Deschamps and Rafael Rodrigues Guimarães Wollmann

1 Introduction

There is an increasing claim for managing engineering courses through competences. By the mid-1990s, the Accreditation Board for Engineering and Technology (ABET) recognized that the international challenge of competitiveness was in part a problem of competencies in engineering education and adopted a revolutionary method proposing the concept of student outcomes (SO) [1]. The importance of this approach is increasingly recognized, even in today's digital transformation era. The purpose is to evaluate what students have learned instead of what students were being taught [5].

This paper focuses on ABET's continuous improvement criterion, which states: "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which SOs are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program" [1]. The continuous improvement process should be designed to evaluate PEOs (Program Educational Objectives) and SOs (Student Outcomes). PEOs are "broad statements that describe what graduates are expected to attain within a few years after graduation", while SOs are defined as "what students are expected to know and be able to do by the time of graduation" [1]. Recently, ABET disclosed a new version of SOs to the 2019−20 accreditation cycle. According to ABET, SOs are outcomes (1) through (7) plus any additional outcomes that may be articulated by the program, as seen next. Indeed, as the new SOs version is very recent, this paper brings out a pioneering approach.

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- SO 1: An ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- SO 2: An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- SO 3: An ability to communicate effectively with a range of audiences.
- SO 4: An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- SO 5: An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- SO 6: An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- SO 7: An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The determination of where, how, and when to assess SOs must be defined by each engineering program individually [5] and there are few papers already exploring the process of ABET accreditation assessment [3, 5]. Awoniyi [2] presents a template that can be used to organize the efforts to satisfy ABET EC 2000 requirements, focusing mainly on criteria 2 and 3 [2]. Felder and Brent [6] also focus on assessment criteria, but the authors bring out an additional contribution since they make clear the difference among some important concepts such as objectives, outcomes, and indicators [6]. McGourty et al. [8] present a more comprehensive approach through the proposition of a five-step process to assess program and make it a model of continuous improvement. There are also other authors that describe their own accreditation process experience. Lohmann [7] describes the Georgia Tech practice and Schachterle [14] approaches the implementation case at Worcester Polytechnic Institute.

Despite the existence of these papers exploring the ABET accreditation assessment, the challenges for establishing such a process are still unclear. A point of attention is to consider both ABET scenario and particularly institution context. Beyond that, there is no publication that proposes a suitable model to Brazilian Institutions in Engineering Education.

In doing so, this paper proposes a Continuous improvement framework to the Engineering Education area, including Performance Measurement Systems (PMS). We propose an eleven-step systematic process to develop an integrated assessment of engineering programs. The procedural framework includes considering external and internal requirements and is based on an in the deep bibliographic review which is not the focus of this paper.

The Industrial Engineering (IE) Program at PUCPR, in line with its efforts to improve and maintain the quality of engineering education, initiated external evaluations towards accreditation by the Accreditation Board for Engineering and Technology (ABET). The proposed framework is tested in the IE Program at PUCPR, located in Brazil. By means of a qualitative approach, it uses action research, since the authors are involved with the development and testing of the proposed framework. Action research is the methodology used in projects in which practitioners seek to effect transformations in their own practices.

2 Proposed Continuous Improvement Framework

This paper uses Platts and Gregory [10] model as a strategy to propose a framework to continuously improve an engineering program. These authors propose a tool to conduct audits to the manufacturing strategy formulation process. They suggest some steps, through worksheets (WS), for manufacturing audit in the process of strategy formulation. Such steps are used as a reference to develop a proposed framework that seeks to attend the continuous improvement of ABET requirement. Table 1 shows Platts and Gregory's propositions in the two first columns and the equivalent in the proposed framework in the remaining columns.

2.1 Framework Steps

Steps presented in Table 1 are also coherent with the DMAIC Cycle and allow the development of an integrated assessment of engineering programs (see Fig. 1). The implementation at PUCPR is described in each step and lessons learned are shared. PUCPR's IE Program, in Curitiba, Brazil, has around 600 students and started its activities in 1998. The program has started to apply this continuous improvement framework in the first semester of 2017.

Step 1—Identify market view of competences. PEOs must reflect the needs of the program's various stakeholders [1]. That is why getting plenty of external views is included in this framework step. This step covers the gathering of specific views concerning the professional market and requirements for an Industrial Engineer. It should be carried out every three years. This is of primary importance since it is only possible to develop students according to necessities if market expectations are well known.

At PUCPR, structured interviews and surveys were conducted in this phase with IE professionals, seeking to reflect the needs of the program's various stakeholders. They were asked to list the important technical knowledge, abilities and behavioral factors desired in an Industrial Engineer. In 2016, 17 interviews were carried out with professionals from industry, including alumni that graduated between 2006 and 2015. In 2018, a survey was promoted to cover a larger number of respondents. 869 alumnis were invited to answer the survey, and a final number of 83 responses was obtained, which is equivalent to about 10% participation.

Step 2—Define/Review competitive professional profiles (PEOs). This step is about the establishment of PEOs which are considered a way to declare external

Table 1 Proposed framework steps

Audit process			Engineering education program process		
WS	Name	#	What?	How?	Objective
WS01	Competitive profiles	#1	Identify market view of competences	Analyze data from industry	Identify most important technical knowledge, abilities, and behavioral factors to the market
		#2	Define/review PEOs		Define PEOs
WS02	Basic data		Not Applicable		
WS03	Competitive criteria	#3	Identify requirements for competences	List internal and external considerations	Align SOs
		#4	Define Program SOs	Deploy PEOs into SOs	Establish coherent SOs, related with PEOs
		#5	Develop a PMS	Define criteria for PMS	Get a coherent PMS
WS04	Achieved performance	#6	Direct Assessment Evaluation	Implement PMS to evaluate SOs	Identify in what extent SOs are being developed to deliver PEOs
		#7	Indirect assessment Evaluation		
WS05	Opportunities and threats	#8	List opportunities and threats	Summarize results as opportunities or threats	Look at opportunities and threats
WS06	Existing practices	#9	List existing practices—causes	Identify what is contributing to poor performance	Identify causes of poor performance
WS07	Action worksheet	#10	Develop improvement and corrective actions	Develop alternatives to overlap poor results	Establish actions to improve results
		#11	Follow actions	Control deadlines and continuously measure the process	To guarantee actions implementation

expectations. They need to derive from the institution's vision. Based on the results of the previous step, PEOs were written at PUCPR and validated with PUCPR's IE faculty. The establishment of an Industry Advisory Board (IAB) from market is considered in this phase to discuss program structuring, always looking forward to being aligned with external claims. This IAB is composed by faculty and market professionals of different companies. PUCPR's IE Program promotes an IAB meeting twice a year as part of the process of understanding program's various stakeholders needs.

The first PEOs declaration proposal was discussed and validated by the IAB in October 2017. Once they were validated, the timeframe for alumni to achieve the PEOs is between 3 and 5 years. The PUCPR PEOs first version is as follows:

- PEO 1: Enhanced organizational performance through assertive decision-making in projects and operations management.
- PEO 2: Created value for stakeholders by promoting innovative solutions (product, process and technology) or by solving complex problems.
- PEO 3: Performed as a transformer of the existing reality, in an ethical and sustainable way, striving for continuous education.
- PEO 4: Lead and motivated multidisciplinary team member through communicating appropriately for the context in an assertive manner.

Step 3—Identify requirements for competences. Program SOs and PEOs must be coherent with a set of internal and external requirements. This is context-driven and depends on each university. Elements such as strategic vision and internal and external political requirements should be considered. In case of PUCPR's IE Program, there are internal requirements from the pedagogical university department to be

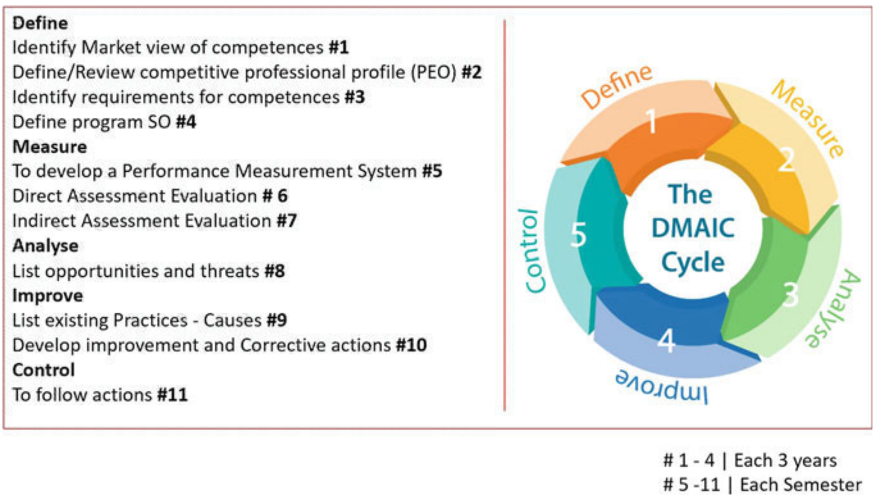

Fig. 1 Continuous improvement processes of the Industrial Engineering program at PUCPR

considered, and external requirements from MEC (Brazilian Ministry of Education) and the Brazilian Board of Engineers (CONFEA/CREA).

Step 4—Define Program SOs. ABET establishes a reference model to SOs definition, as it prescribes a well-known list of expected SOs. The set of PEOs drives the assessment process, therefore it is important to have completeness between PEOs and SOs. Based on program characteristics, PEOs and ABET (1)−(7) SOs recommendations, SOs must be defined in this step. 'Competitive criteria' [10] are considered the SOs in the proposed model. SOs from PUCPR's IE Program have the same description as suggested by ABET. The relationships between PEOs and SOs are as follows: PEO 1 helps in SOs 1, 2, 4, 6 and 7; PEO 2 helps in SOs 1, 2, 4, 6 and 7; PEO 3 supports all SOs; PEO 4 contribute to SOs 3, 5 and 7.

Step 5—To Develop a Performance Measurement System (PMS). According to ABET criteria 2018−2019, the extent to which student outcomes are being attained needs to be evaluated and documented. It can be accomplished through direct and indirect measurement processes.

Indirect assessment is the evaluation obtained without directly observing the students work. This kind of assessment is important to evaluate specific cases, especially regarding professional skills, which are difficult to evaluate by traditional direct assessment methods [13]. Direct assessment can be obtained in class exams, written lab reports, National Standard Tests and performance evaluations in oral presentations. As indirect assessment examples, the author proposes student perception surveys, graduate school placement rates, employer or alumni surveys and senior exit interviews [5].

Direct assessment is when the evaluation is directly performed from student work. It can be compiled with well-defined indicators. ABET defines that the indicator is what faculty are going to look for in student performance to have confidence that, by the end of the program, students can demonstrate the learning outcome.

At PUCPR, the evaluation of SOs attainment is accomplished through direct and indirect measurement processes, as detailed in Table 2.

The first is performed by Program Criteria (PC) evaluations, and the second by a set of surveys. The senior student survey seeks to ponder the perception of the level of SOs development and satisfaction within the program and should be conducted with last semester students by the time of graduation. PUCPR's IE Program conducted its first PC evaluation in the first semester of 2017 and is in the fourth measurement cycle. The evaluation through the PCs encompasses the design of the PMS, in which steps

Table 2 SOs measurement

Capture data method	Way of measuring	How to evaluate
Direct or indirect assessment method	PC definition for each SO	Evaluate PC at selected courses
Indirect assessment method	Overall student outcome evaluation	Senior student survey

are proposed to develop a PMS coherent with the context of measuring performance in Engineering Education.

The definition of high-level PCs associated to each SO is included in this step. In this way, it is important to guarantee that the set of PCs embraces the intention of each SO. Each SO should be associated with two or more PCs describing the characteristics, skills, knowledge, attitudes, and/or values that students must exhibit to demonstrate the achievement of an SO. To have completeness in PCs definition, Pettigrew et al.'s [12] framework was used as a foundation to define the indicators. To fulfill it, each SO has PCs regarding context, content, and process. The context can be both external and internal. The first regards to the economic, political, and competitive environment in which an organization operates. The internal context refers to the structure, corporate culture, and politics. Content is about the area of transformation under examination, as technology, manpower, products, geographical positioning, or organizational culture. It regards to objectives and assumptions, targets, and evaluations. Finally, process regards actions, reactions, and interactions from the various interested parties as they seek to move the firm from its present to its future state [11].

At PUCPR, after meetings involving all faculty, PCs were defined. An example for PCs defined for PUCPR's IE Program are presented in Table 3. The PCs are assessed on courses and an evaluation is conducted by each responsible faculty.

PCs are mainly assessed in courses and the evaluation is conducted by each responsible faculty. It is recommended that PCs of the same SO be evaluated in different courses. To have an overview about courses that can measure each PC, it was suggested the development of a correlation matrix, attributing in which level each course is able to develop each PC. Three levels of contribution can be determined, for example.

Table 3 PUCPR's IE Program Performance Criteria (PC) for SO 1

SO	PUCPR IE PC	Completeness evaluation
(1) An ability to identify, formulate and solve complex Engineering problems by applying principles of engineering, science and mathematics	Apply IE knowledge, techniques and modern tools, in an integrated way	Content
	Apply mathematical analysis (calculation, statistics and algebra) revealing accuracy	Content
	Represent (illustrate) a real-world situation in an appropriate mathematical model (formulate a problem)	Process
	Completely define an engineering problem	Process
	Formulate a complete solution for an engineering problem	Process
	Demonstrate an Industrial Engineering problem solution using software and applying techniques of data and process modeling	Context

Strategy:			Strategy Code:						
#	Performance Criteria (PC)	Proposed evaluation activity Ex:. Exam, question inside na exam, individual work, team work, oral presentation, case study...	Application Situation (Detailed description of the proposed activity)	Evaluation instrument (Ex: Rubric, check list of criterias, proof template...)	Evaluation instrument Code	Year	Semester	Weight of the indicator in the course grade (%)	Comments

Fig. 2 Specific PC standards sheet

PUCPR's IE Program faculty are invited to participate in the process of mapping SOs and PCs correlation through a survey. The used correlation levels of each course in the PC were introduce, reinforce and emphasize.Each faculty attributed the level of correlation for courses that they felt comfortable to analyze. Only specific program courses were considered in the mapping, as this is easier to manage within faculty under the leadership of the program. Through the result of this mapping, it was possible to select the courses able to measure each of the PC. Furthermore, this mapping provided a holistic view about SO development, making it possible to know at which stage a SO is developed and, then, contributing to defining the requirements for each semester.

The Performance Measure Record Sheet was then developed to formalize the PC standards. Such a sheet is based on Neely et al. [9] that proposed the performance measure record sheet, summarizing works approaching what a good performance measure constitutes. Each PUCPR's IE responsible faculty must detail and document the measurement strategy for the respective PC through the 'Specific PC Standards Sheet'. A template can be seen in Fig. 2.

Steps 6 and 7: Direct and Indirect Assessment Evaluation. A simplified sample of measurement results is presented in Fig. 3, which represents the direct assessment report. As mentioned before, there is also the Senior Student Survey an indirect assessment process to avoid bias on results. It encompasses another perspective of evaluation: the student view. A senior student survey is planned to collect student's opinions about the contribution of PUCPR's IE Program in developing each SO. Such a survey also looks at understanding student's satisfactions and employability data.

Steps 8 and 9—List Opportunities and Threats/List Existing Practices—Causes. This is an analytical step that seeks to summarize results from direct and indirect measurement as opportunities or threats. This is important to avoid threats and explore opportunities within action plans. It is vital to recognize results lower than expected and investigate reasons to such results. A well-developed root cause analysis is of primary importance to develop a consistent action plan and should be developed in this step. A continuous improvement group can be established in this phase. Based on direct and indirect measurement results, PUCPR' IE Program defined priorities

3. An ability to communicate effectively with a range of audiences.			Last Measurement
#	Measure title- Performance Criteria (PC)	Strategy	
PC-EP-3.01	Effectively communicate in writing in transmitting arguments and contents to readers (grammar, logical sequence, formatting, content).	Capstone Project	2018.2
PC-EP-3.02	Report the final result (of a design experience) using context-appropriate language.	Capstone Project	2018.2
PC-EP-3.03	Demonstrate ability to synthesize results in graphic form providing a complete overview of the results.	Organizational Engineering	2018.2
PC-EP-3.04	Report the final result using context-appropriate language.	Engineering Project Management	2018.2
PC-EP-3.05	Clearly communicate, displaying self-confidence, resourcefulness, appropriate use of the standard language and technical repertoire of the area	Services Management	2018.2
PC-EP-3.06	Present work in a clear, clean and precise manner	Organizational Engineering	2018.2

Results Overview

Course Status

	Students Quantity					Results			
#PC	Students Total	Excellent	Acceptable	Unacceptable	Not evaluated	Target	2017.2	2018.1	2018.2
PC-EP-3.01	64	21	24	10	9	70%	73%	78%	82%
PC-EP-3.02	64	29	11	15	9	70%	72%	75%	73%
PC-EP-3.03	30	30	0	0	0	70%	100%	100%	100%
PC-EP-3.04	30	20	5	5	0	70%	100%	76%	83%
PC-EP-3.05	47	22	25	0	0	70%	N.A.	100%	100%
PC-EP-3.06	30	18	12	0	0	70%	100%	98%	100%

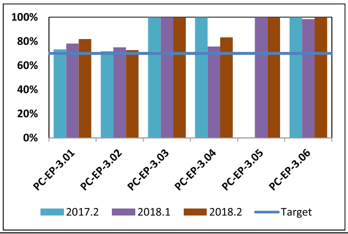

Fig. 3 Sample of SO evaluation through PC

to take actions. An annual meeting with faculty is organized to discuss results and defining priorities for action. A root cause analysis is conducted to prioritize weak points selected by faculty.

Steps 10 and 11—Develop Improvement and Corrective Actions/Follow Actions. Actions should be established considering the analysis in Step 9. This is the key step to stimulate continuous improvement. The action plan introduces alternatives to address poor results. Additionally, this phase includes the daily management of planned actions and results, to guarantee continuous improvement. It is important to check realization and results of undertaken actions.

An action plan is established seeking to improve PUCPR's IE Program results. Additionally, always when a weak point is identified, an improvement plan is also required. PUCPR's IE Program has developed an improvement procedure that encompasses the steps to guarantee the process realization in long term. The established actions must be implemented, and it is the responsibility of the Program's leadership to ensure that the actions are carried out.

The eleven presented steps, in this sequence, are part of a continuous improvement process. The stages need to be performed frequently. To be a feasible process, different frequencies to realize each step are suggested, as some processes are more demanding. Keys for an effective assessment tool requires low faculty effort to develop, administer and maintain the process [3]. Steps 1−4 can be developed every 3 years, but Steps 5−11 need to be developed every semester, to collect data from a considerable number of students and to implement improvement actions more dynamically.

3 Conclusion

The paper attains the objective of proposing a process to continuously improve performance in the context of Engineering Education. The developed framework needs to be implemented with faculty support. In doing so, it is important to make the process easy to be used in the faculty's routine. PUCPR's IE Program has a continuous improvement procedure that documents every criterion in a more detailed way.

There are some opportunities for improvement in the presented framework. It is recommended to expand the market view, collecting a wider overview about market requirements for an IE Program. It is possible to enhance the quantity of interviews and apply other methods of data collection to accurately map alumni profile. The application of a survey is suggested to get more opinions from different stakeholders. The CDIO questionnaire can be used as the basis for this survey [4]. It is recommended to conduct this survey with alumni, market professionals, and faculty.

As a future opportunity of work, necessity to evaluate the consistency of the proposed model is pointed out. It is believed that, to be effective, the process of measuring and improving SOs must be coherent with external requirements, regulatory institutions such as MEC (Brazilian Ministry of Education) and the Brazilian Board of Engineers (CONFEA/CREA), and have internal needs reflected by the strategic vision of the educational institution.

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Internet of Things (IoT): Technological Indicators from Patent Analysis

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1 Introduction

Connecting various devices over the Internet for the exchange of information in the industry is already possible through the Internet of Things (IoT). The term was first assigned to work developed by Auto-ID Labs on Massachusetts Institute of Technology—MIT on research about Radio Frequency Identification—RFID [1]. IoT is related to research of Gershenfeld [2], which a scenario is modeled as a set of objects able to process information.

IoT applications have different uses and can be adapted to a very large amount of areas such as smart industry, smart buildings, smart health and other applications to

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smart cities. Also, in smart industry, there are systems of intelligent production discussed over industry 4.0, changing the means of acquire, processing, and distribution of basic material and finished products. In smart buildings, we have the construction of buildings based on measurers, safety systems, and apps to provide the monitoring of safety issues, electricity, water, and even gas. Also, in smart mobility, it is possible to monitor the vehicular route, ticketing emission and measure the user patterns to provide solutions for traffic in big cities. In smart health, it is possible to watch patients and chronical diseases follow-up. Finally, we can do real monitoring of smart cities projects such as parking space, illumination and the occupancy of streets and public areas [3].

The Internet of Things is such a vast reality that it has become an umbrella term for many underlying use cases, technologies, and other aspects. In the context of industry changes such as the introduction of automation systems, cyber-physical systems, and the Internet, the industry 4.0 emerged. Industry 4.0 is a new industry revolution that succeeds in three previous revolutions. In order to allow the realization of industry 4.0, it is necessary to use technological infrastructure composed of virtual and physical systems powered by information and connections from simulations, augmented reality, big data, IoT, and robots. Therefore, it is necessary a friendly environment for building and incorporating these new technologies.

The growth of devices connected to Internet increased over the last years. According to European Commission Information Society and Media, there will be $50-100$ billion of connected devices to the Internet [4]. All this, together with the ideology of smart homes, smart devices and intelligent transportation are the main core of an infrastructure that may connect our world more than we ever thought possible. In this context, the Internet of Things (IoT) emerged as an expected solution for building a world where things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network [5].

Thus, IoT implies a very promising concept to build powerful industrial systems and user needs-based applications. Furthermore, in an economic perspective, the value generated by IoT technologies is estimated in a value of 33 trillion dollars [6]. In order to allow the IoT behave properly, IoT bundles different technologies together such as: sensors, semantic, data modeling, cloud computing, communication protocols, storing, and hardware manufacturing.

There is a growing consensus that IoT is also taking a leading role in digital transformation in a wide variety of business applications in locations around the world [7]. The interconnection among objects and things enables many possible applications in many domains. Essentially, these applications can be divided into three categories based on their focus [4]: industry, environment, and society. Table 1 highlights some very promising applications under the IoT main categories.

IoT applications have different finished and can be adapted to a very large amount of areas such as smart industry, smart buildings, smart health and other applications to smart cities. Also, in smart industry, there are systems of intelligent production discussed over industry 4.0, changing the means of acquire, processing, and distribution of basic material and finished products. In smart buildings, we have the construction

Table 1 Promising applications under three IoT categories

Category	Applications
Industry	Transportation and logistics
	Aviation
	Autonomous driving
Environment	Agriculture and breeding
	Environmental monitoring
Society	Healthcare
	Smart home
	Entertainment

of buildings based on measurers, safety systems, and apps to provide the monitoring of safety issues, electricity, water, and even gas. Also, in smart mobility, it is possible to monitor the vehicular route, ticketing emission and measure the user patterns to provide solutions for traffic in big cities. In smart health, it is possible to watch patients and chronical diseases follow-up. Finally, we can do real monitoring of smart cities projects such as parking space, illumination and the occupancy of streets and public areas [3].

Future expectations about the use and apps for IoT are emerging. However, there is a set of challenges to be overcome which include technologies and operational issues, aside from strategical issues from emerging business models. Thus, it is necessary to identify threats and opportunities. So, existing business models have to adapt to the new positioning of these products [3].

It is possible to know how much a subject has been developed and also forecasts about future expectations. For that, you can monitor products on the market, scientific articles or patent documents. Patents represent a valuable asset and a competitive resource at the disposal of companies. Patents allow the sole exploitation of the product, excluding third parties. In addition, patents can also be used as technological information. In this way, patents can be used as input for new research and development processes [8]. The technological monitoring process through of patents related to IoT allows to know the technological scene on this subject.

With the volume of data produced by machines and people on a daily basis becoming unmanageable, companies need to have a plan of how they will use IoT in their business and how they will protect its data. The objective of this article is to present the overview of patent documents related to the internet of things, in view of their importance for Industry 4.0, identifying the evolution and the main technological subdomains and the depositor countries.

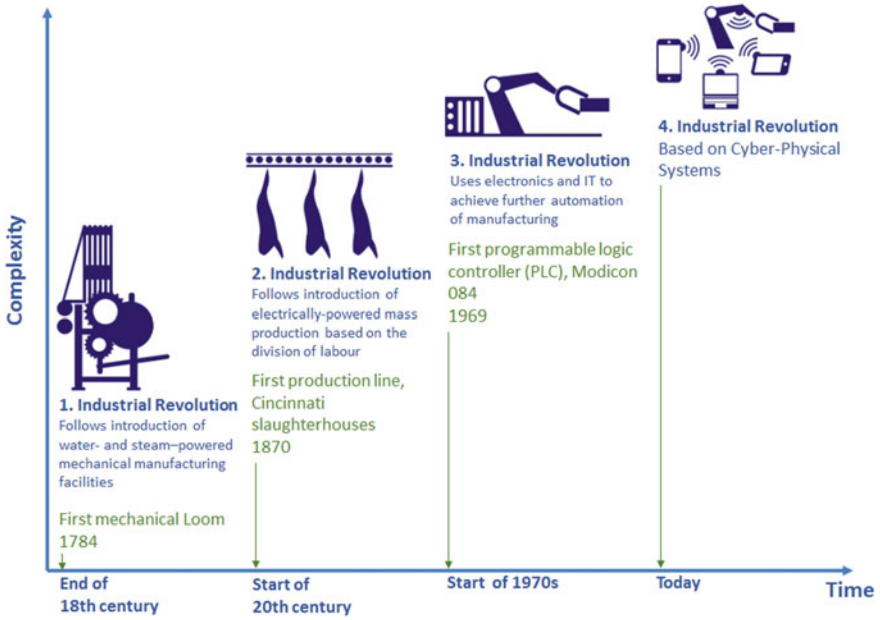

Fig. 1 The four stages of industrial revolutions [9]

2 IoT in Industry 4.0: The Future of Connected Industry

Factories have machines, process, and devices that supplement operations. These industrial units can be connected to Internet, allowing interconnection between data and systems, so industrial plants can be digital over industry 4.0.

As presented, the term industry 4.0 emerged to characterize a new industrial revolution that succeeded in the previous three revolutions. The first industrial revolution occurred in the late eighteenth century and was characterized by the mechanization of production, favored by the emergence of the steam engine. The second industrial revolution occurred in the early twentieth century with the emergence of mass production, the division of labor, and the development of the Taylorist and Fordist Systems of production, including the use of electric power. The third industrial revolution began in the 1970s and was driven by the use of electronics, information technology, and greater automation of production processes [9]. Figure 1 summarizes the key development factors achieved in industrial revolutions over time.

Industry 4.0 is based on four main elements: Cyber-Physical Systems, Internet of Things (IoT), Internet of Services (IoS), and Smart Factory. Cyber-Physical Systems (CPS) are constituted by actuators and intelligent sensors which allows information systems to do the physical control of production processes. IoT allows data sharing among devices that control production processes in real time using wireless networks. Internet of Services allows each service can be performed using machine-to-machine communication or supplier to factory to generate information data. Finally, on Smart Factory, the cyber-physical communication using IoT helps machines and people in tasks execution [10].

So IoT is one of the cornerstones of the 4.0 industry by allowing the connection between machines, vehicles, and other physical objects through embedded electronic devices. IoT enables the exchange and collection of information, and also decentralizes analysis and decision making, allowing responses to occur in real time.

3 Sources and Methodology

A patent document contains, in a standardized form, a wealth of information about the state-of-the-art about cutting-edge technologies that is often not available in another document. Therefore, they are an important information source to disseminate science and technology information. But, as a first step, it is essential to grasp clearly the basic concepts of the patent system so as to appreciate better the practical usefulness of patent as a rich technological information source. Therefore, the works elaborated by Ardito et al. [11], Milanez [12] and Wang and Hsieh [13] are highly recommended because contribute to understand the universe of research.

3.1 Derwent Innovations Index

In this study, technological indicators were developed using patent documents data indexed in the Derwent Innovations Index (DII). Integrated to the Web of Science platform, it is a patent database that covers value-added patent records from Derwent World Patents Index with patent citation information from Patents Citation Index. It is updated weekly and contains over 16 million basic inventions, with coverage from 1963 to present. Patent information is drawn from 41 patent-issuing authorities around the world and is categorized into three categories, or sections; Chemical, Engineering, and Electrical and Electronic. This database allows for complex Boolean searches in multiple bibliographic fields, such as the title, abstract, inventors, assignees, and International Patent Classification (IPC).

3.2 Methodological Procedures

Patent information is very important to the policymaker, but it is necessary to collect and analyze a large number of patent documents through tools, such as a data mining, in order to make a decision. Therefore, this study has been conducted following the next steps:

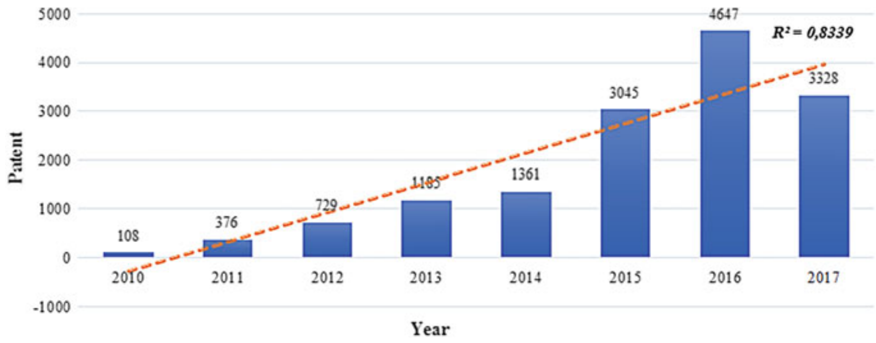

Fig. 2 Annual number and annual growth rate for patent documents about "internet of things" from Derwent innovations index in the period between 2010 and 2017

- Definition of search expression;
- Search of bibliographic records in database;
- Bibliometric analysis;
- Graphic representation; and
- Analysis and presentation of results.

The following set of bibliometric indicators was developed:

- Number of patents per year and annual growth rate from 2010 to 2017;
- Patents documents per country of origin;
- Distribution of patent documents according to technological subdomains.

4 Results

A total of 14.763 patent documents related to IoT in the period from 2005 to 2017 were identified. The term was introduced in 1999 by Kevin Ashton in the context of RFID-related supply chain management [14]. Therefore, in 2005, we have the first patent document indexed in the DII related to the subject and it approaches a method for the production of work products. From 2005 to 2009, it presents only 6 patent documents, of which four are from 2009. It was noted that only from 2009 to 2010, there was a growth rate of 2600% of patent documents.

The evolution of the number of patent documents between the years 2010 and 2017 is presented in Fig. 1. The year 2016 stands out with 4647 patent documents, however, the year 2017 in future research may present a greater amount of documents, since not all patents referring to this year may have been indexed in the DII, having in view, that the data of this research were collected in early 2018 (see Fig. 2).

The databases normally depend on the availability of information from the intellectual property offices of each country and account should be taken of the confiden-