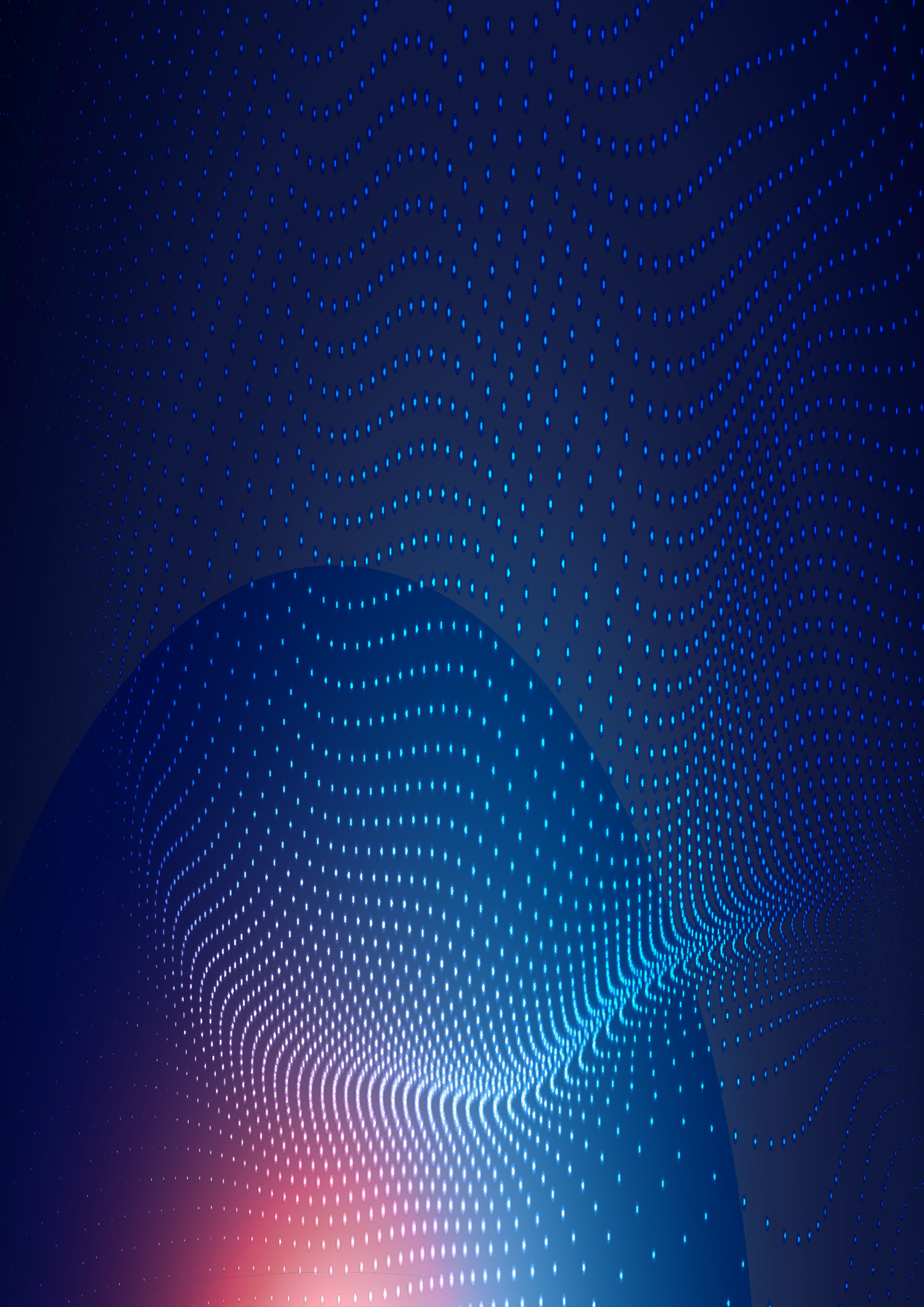
ISSN

JOURNAL IDEAS

Facultad de Ingeniería en Ciencias Aplicadas
FICA

Nº1
Volume 1
June 2019

Innovation & Development in Engineering and Applied Science



JOURNAL

IDEAS

Innovation & Development in Engineering and Applied Science

FACULTAD DE INGENIERÍA EN CIENCIAS APLICADAS

FICA

IBARRA - ECUADOR

2019

EDITORIAL COMMITTEE

Imprenta Universitaria 2019
Universidad Técnica del Norte
Ibarra-Ecuador

EDITORIAL UTN
IBARRA - ECUADOR

EDITORIAL

Welcome to Innovation and Development in Engineering and Applied Science of the Universidad Técnica del Norte. We are an open-access journal, where original and unpublished scientific results, technical case studies and innovative engineering works are published after a double-blind peer review, with a frequency of two-issues per year. It is aimed at the academic and professional community in subjects related to engineering and applied science.

The IDEAS journal is open to articles from disciplines such as:

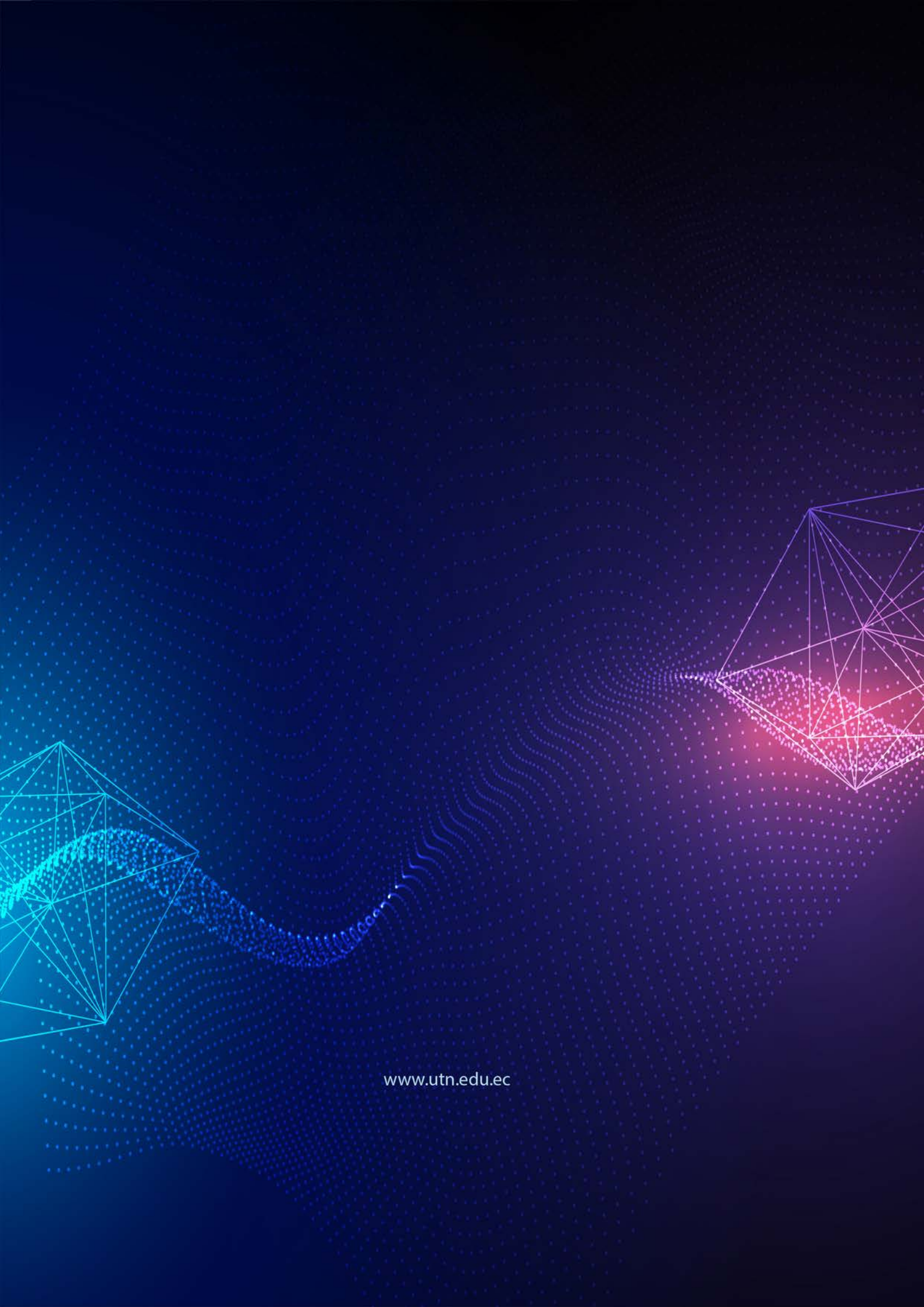
- Mechanical, mechatronics, vehicle, and materials engineering
- Information and electronics engineering
- Energy and environmental engineering
- Textile industries engineering
- Agriculture
- Bioengineering
- Industrial engineering

In each issue, we strive to achieve a balance amongst the different disciplines. Therefore, accepted articles are selected in order to achieve this goal, and it can affect the sequence in which they are published. If this were the case, authors will be able to take the decision to withdraw the application of their article or to let it be published in a subsequent issue.

Contact between authors and reviewers is under the responsibility of the Editors and Editors of the Section, thus ensuring that these processes are conducted anonymously.

INDEX

June 2019



www.utn.edu.ec

Web apps characterization, a first step for usability evaluation

gihernandez@umariana.edu.co
carlos@udenar.edu.co
amartinez@umariana.edu.co

Giovanni Albeiro Hernández Pantoja, Carlos Hernan Guadir Aza, Alvaro Alexander Martínez Navarro
University of Nariño, Mariana University
Pasto - Colombia

gihernandez@umariana.edu.co, carlos@udenar.edu.co, amartinez@umariana.edu.co

About the authors

Author 1: Systems Engineer, postgraduate degree in Computer Management and Master in University Teaching. Full-time professor at the Mariana University (Pasto, Nariño, Colombia). Associate Researcher (Colciencias).

Author 2: Systems Engineer. University of Nariño (Pasto, Nariño, Colombia). SERATIC Development engineer.

Author 3: Systems Engineer, Master in University Teaching, Master in Analysis and Massive Visualization of Data. Full-time professor at the Mariana University (Pasto, Nariño, Colombia). Associate Researcher (Colciencias).

ABSTRACT

The main goal from this article is characterize the web apps developed as grade works, in Systems Engineering's program of Nariño University; as a first step for usability evaluation. This effort was carried out under empiric-analytic approach, of descriptive type. The object population of the study was the web apps developed as a grade works in Systems Engineer-ing's program of Nariño University the years between 2010 and 2017. As a result, web apps were characterized, bearing in mind the variables: quantity, technology, economic sector, de-velopment time, involve and current state. Was identified 71 grade works that developed web apps, where PHP is the back-end language used and a high level does not identify the use of front-end frameworks. In intermedium level, the web apps were developed by one student only. In a high level the web apps were to public entities, being the sectors: education, government and service; the most bounties. The work enables us to conclude that the lowest use of web apps, obey to the relation between software architecture and usability. The intermediate use of back-end web frameworks and the low level of use of front-end frameworks, is a factor that decreases the flexibility to implement usability architectonic tactics a web app. Moreover, teamwork has to be encouraged and propitiate, when software is build.

Keywords: Usability, Usability Evaluation, Web Applications, Web Usability.

Introduction

Software usability is a study field from Human-Computer Interaction discipline and is considered as a non-functional attribute that requires a process and engineering to handle it systematically through replicable and flexible methods (Taylor and Francis Group, 2014); its purpose is the user-centered design, which is the basis for a successful interaction process. The content is the primary reason for interacting with a software product.

At the Systems Engineering´s program of the University of Nariño, the requirement for the undergraduate degree is performing a deepening project by students. Additionally, this work allows integration and theoretical or theoretical-practical application of knowledge, skills and attitudes; to contribute to the analysis and solution of a problem related to the object of study or an area of the profession (Ordoñez, Hernández Pantoja, Ordoñez, Ordoñez, & Cobos, 2016) (Ordoñez, Ordoñez, Ordoñez, Cobos, & Hernández, 2017). Between 2010 and 2017, 30% of the degree works done by the students were development of web applications. This behavior, although it is not stable, is almost always superior to another type of degree works, because trend of use of web applications is increasing, as well as devices connected to the Internet (ICT Ministry, 2016) (Burak Tekin and Tufekci, 2013).

On the other hand, software development requires quality standards like usability attribute. This is defined as a non-functional attribute of a product or software system; specific users can use it to achieve efficiency and relative satisfaction in a specific context of use (ISO 25000 Standards, 2018). However, a document inspection for web development works revealed that, 93% of them didn't explicitly identify usability as a non-functional requirement.

Not including usability at the time of software implementation implies that this attribute of quality is not consciously assumed. In addition, by doing an inspection of the curricula, it was possible to identify ten elective subjects, which students can take during the training process. However, none of them focuses on developing skills in building software in a usable way.

Making an inspection of degree works between 2010 and 2017, it was identified that web applications developed were projects for public and private sectors. In this ways,

the responsibility for software quality in terms of usability becomes a highly desirable attribute; otherwise, as Sanchez (2011) states, web applications poorly usable are definitely abandoned by users since the complexity of use does not allow them to concentrate on activities.

According to the number of web applications developed in degree works and tendencies for using this type of systems, it can be inferred that the percentages will be maintained with a high probability of increasing them. In addition, web applications face a diversity of clients with limitations that require improvements in the content architecture (Lund and Sieverthson, 2017).

The characterization takes different meanings. Nevertheless, the Royal Spanish Academy (2018), defines it as the result of determining the peculiar attributes of something, so that it clearly distinguishes itself from the others. In this way, it is understood as the result of establishing which are the properties that an object has, in relation to a set of variables or indicators, that allow identifying distinctive features as an input to describe an initial state.

Usability has been defined as an attribute of a software product, this can be learned, understood, used and it may be attractive to the user, when it is used in certain contexts (ISO 25000 Standards, 2018). Also, it is understood as a quality attribute that measures the easy-to-use of user interfaces (Jakob, 2012). It is a feature that a software product has to be understood, used, and allows a user to develop a task in a simple way, when used under specific conditions.

Usability evaluation means to apply methods that identify and measure usability problems, and then suggest practical solutions that specify how they could be improved. The methods to evaluate usability have two approaches: subjective and objective. Each approach attempts to measure the interactive user experience (UX) associated with the interface. The usability analysis provides an understanding of UX that helps determine where and how to redesign the interface (UI) to improve the level of interaction and satisfaction (Nagpal, Mehrotra, and Kumar Bhatia, 2017).

The subjective approach according to Fernandez, Insfran, and Abrahão, (2011) and Ndako, Shehi, Adelowo, and Gbenga (2017) divides into three types. Inspection, involving experts evaluating user interface based on design principles and guidelines, group tours or inquiry, a technique carried out by stakeholders of the product simulating common activities in prototypes of the web application, and the third type are user tests, selecting prospects from potential users, to execute specific activities in the software product.

For the previously described, this research was born, which aimed to characterize the web applications developed as degree works, as a first step of the evaluation of subjective usability, in the Systems Engineering program of the University of Nariño.

2. Materials and methods

The research that supports this article was made under the quantitative paradigm, with an empirical-analytical approach of a descriptive type. The studied population were the web applications developed as degree works in the Systems Engineering program of the University of Nariño (Colombia) during the years 2010 to 2017. No sampling was done, it was used the total of web applications developed as degree work during the period from

2010 to 2017. The technique used to collect the information was the documentary review, where a matrix of characteristics and properties was built as an instrument. For the analysis of the information, descriptive statistics was used as a technique, making a frequency analysis. The variables analyzed were: quantity, technology, economic sector, development time, people involved, and current status.

The quantity variable corresponds to the number of web applications developed in the inspected period, between the years 2010 and 2017. In the technology variable, the back-end and front-end of the web applications are analyzed, in order to know the programming or markup languages; and frameworks used for development. The database management system (SGDB) for each one was also identified, making groups for registered trademarks. In the same way, the Internet servers used to deploy the applications. The economic sector variable has to be with the type of company the web application is developed. The categories defined were public, private or mixed companies. The variable time of development, allows knowing the period required for planning, organization and execution of the degree work. The variable people involved, explores the effort required for the development of the degree work, that is, number of students needed for development. Finally, the current state variable describes web applications in production, that is, installed applications that continue working in the organizations for which they were developed.

The work had 2 stages. In the first one, a list of the degree projects developed between 2010 and 2017 was requested to the Systems Engineering department's direction. Subsequently, a classification of the degree works was made, according to the categories: web applications, desktop applications, applications for mobile devices, Software Engineering, auditing, objects or virtual learning environments, networks and telematics; for those jobs that did not match the previous categories, were included in the "other" category. After that, a report was requested to the director of univerty's library. This final report included degree works categorized as web applications. At Systems engineering's direction, the access to repository and to download the source code was asked. Once the documents and resources were obtained, a documentary review sheet was developed using the Objective-Question-Metric (GQM) technique, based on the defined variables and validated through expert judgment technique. Afterwards, developed web applications were installed and with the final reports of the degree works, the information was compiled, completing a documentary review file for each degree work. Next, a matrix of characteristics and properties was elaborated with the data collected from the documentary review.

On the second stage, it was performed an analysis of data collected through descriptive statistics as a technique, using frequency analysis and constructing categories for the values obtained by each variable and calculating the occurrence of these, through relative and absolute frequencies. These frequencies were moved to frequency tables. Values obtained from the frequency tables were represented by graphs. Finally, on the interpretation of the results, it was described general properties and characteristics of web applications developed as degree work.

3 Results

On the first stage of the investigation, general properties of the degree works made between 2010 and 2017 are described.

3.1 Description of thesis research studies

The highest percentage of thesis research studies is oriented to the development of web applications with a 33%, as can be seen in Fig. 1. They are oriented to software development, because 58% of them developed some kind of software like web applications, desktop applications, mobile applications, video games or applications for other platforms.

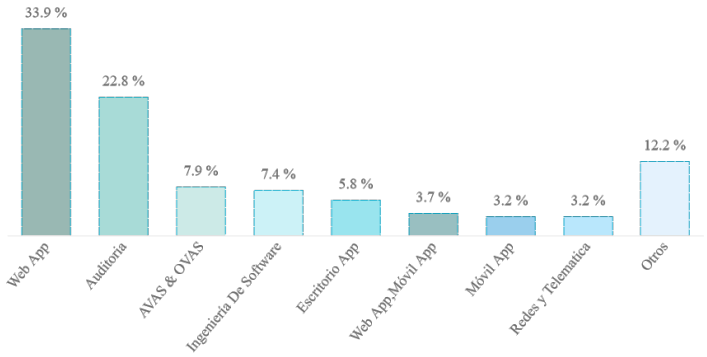


Fig. 1. Types of jobs from grade 2010 to 2017

Fig. 2 shows frequency lines per year for web applications, audits and mobile applications. Audit works have a growth until 2016, between the years 2012 to 2013 they grew by 300%, between the years 2014 to 2016 grew by 225%. Mobile applications developed as degree works show increasing trends, when comparing between 2012 and 2016 a growth curve is evident.

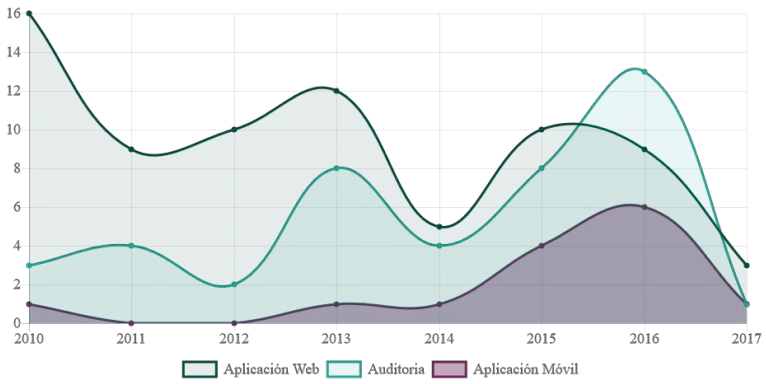


Fig. 2. Web, mobile applications and audits 2010 to 2017

3.2 Characteristics of web applications

The characteristics and properties of web applications developed as thesis research studies were analyzed through the variables: quantity, technology, economic sector, development time, people involved, and status.

The characterization made it possible to identify that web applications are a common product of a thesis research study. Fig. 2 shows the frequencies of web applications per year, with a total of 71 applications developed. Between 2010 and 2011 web applications decreased by 43%, the years 2013 to 2014 had a decrease of 58%. Between the years 2011 to 2013 there is a growth of 25%, and then between 2014 and 2015 they grow 50%.

When developing a software product, tools or technologies are used to implement the functionalities and designs. Web applications require three parts, data layer, business layer (back-end) and presentation layer (front-end).

The logic of the business in a web application, are functions that perform data entry, queries, generation of reports and the required processing, developed under a programming language. As can be seen in Fig. 3, the most used programming languages for the back-end construction were PHP with 49%, followed by C # with 25%.

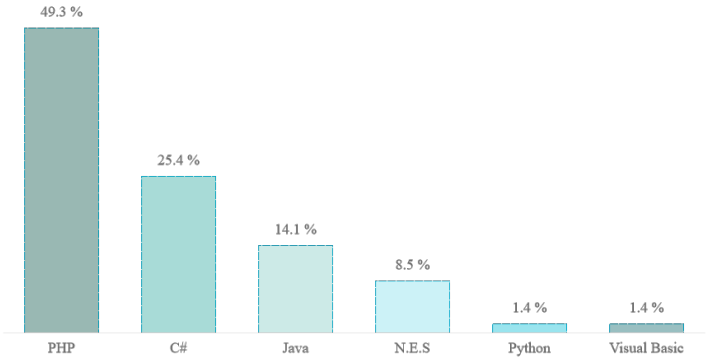


Fig. 3. Back-end programming language

On the other hand, 49.3% of the works did not specify the use of a web framework, followed by .NET[1] with 31%. Another representative group are Java frameworks[2] with total of 11%.

In relation to the front-end languages, it was identified that the most used were HTML (74%), JavaScript (56%), XML (40%) and CSS style sheets (32%). However, 18% did not specify the use of any of the languages.

The most used front-end frameworks were JQuery (12%), a JavaScript library used to implement the AJAX technique and manipulate the DOM dynamically. The documentation explained that these techniques were used with the purpose of improving the usability of the application to be built. Other frameworks used are Bootstrap (5%), JQuery UI (4%), Metro UI (2%) and Prime Faces (2%). In addition, 62% of the degree papers did not document the use of a front-end framework.

The essence of a web application is the access to data in an interactive way, the data is stored, consulted and updated in the Database Management System (DBMS), part of the data layer. In relation to the technologies for DBMS, it was found that 20% of the works used licensed software, such as Oracle[3], Microsoft Access[4], and SQL Server[4]. As free DBMS, PostgreSQL and MySQL were found, with 36% and 32% respectively. In addition, 9% did not specify the DBMS used.

For implementation of a web application, an Internet server is required. Apache servers[5] are the most used with 45%. Internet Information Services (IIS)[4] was used by 22%. This last

1 It is a registered mark of Microsoft Corporation
2 It is a registered mark of Oracle Corporation
3 Oracle: It is a registered mark of Oracle Corporation.
4 SQL Server: It is a registered mark of Microsoft Corporation
5 Apache: It is a registered mark of Apache Software Foundation

proprietary software was used in the majority of web applications developed under the .NET framework. A find of this research is that 31% of graduate works did not document the application server used.

For the economic sector variable, it was possible to investigate the types of companies benefited from the development and implementation of web applications. Public entities have the greatest benefit, with 67%. Part of these works were developed for educational centers such as schools or public service companies. According to (Virtual Business Center, 2016) in Colombia, the economic sectors are grouped by the service they perform or they are grouped by the product they commercialize. According to this, it was identified that the sector of the primary economy, was benefited with 2%, in the activity of Agriculture. The works destined to the secondary sector were of 4% in the Industry activity, and the remaining 94% belong to the third sector in the activities of education, services, government and others.

The sector with more degree projects related to web applications is education, benefiting universities and schools. The government sector is represented by government entities such as Municipalities, and the Health sector in hospitals. Tourism, transport, and solidarity sectors are grouped between 1% and 2%. Fig. 4 shows the summary of frequencies of the economic sectors.

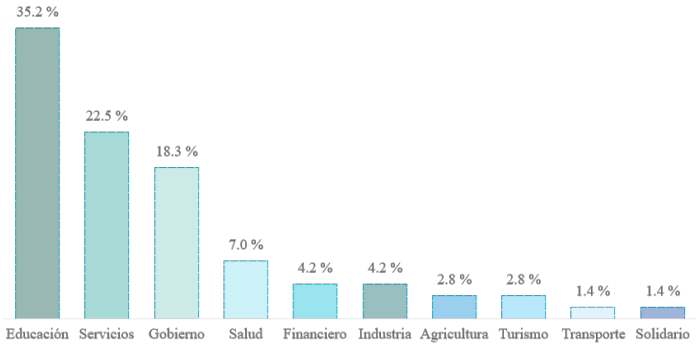


Fig. 4. Economic Sectors

An observation of the final report of degree works, it was evidenced that in 85%, it is not possible to identify the time required for degree work development. The 15% left described a period between 4 and 16 months, with 6 months being the most frequent period with 7%.

For the number of students responsible for degree work, it was found that 59% were developed by a single student. According to Noll, Abdur Razzak, Bass, and Beecham (2017), the methodologies suggest a minimum of three people to fill roles and only 2% meet that requirement. Table 1 shows a summary of people involved in the degree project grouped by gender. In this table, it is observed that women prefer to perform degree work by group. On the contrary, men are the ones who most developed their project individually, with 37% of the total of individuals. In total 80% of people involved in web application development are men and 20% are women. Number of professionals who graduated in a degree project related to the web application development was 107 students.

Table 1. People Involved at degree work

Number Involved	Male		Female		Total
	FO	% FO	FO	% FO	
1	40	93%	3	7%	43
2	42	72%	16	28%	58
3	4	66%	2	34%	6
Totals	86	80%	21	20%	107

An examination of the use of web applications in entities for which they were developed found that 8% are in operation.

3.3 Discussion of results

A recent study on usability by Maat, Swaid, Krishnan, Ghoshal, and Ramakrishnan (2018), proposed a framework for evaluating usability in software products focused on analysis and visualization of scientific data. The framework described is an expansion of Nielsen's heuristics, adapting additional criteria that capture dimensions of usability in the specific type of software. Although Maat, and others (2018), evaluates software products using subjective techniques such as Nielsen's heuristics, in this research, characterization is considered as a preliminary step to subjective evaluation focusing on a type of software such as Web applications.

In the investigation by Elberkawi, El-Firjani, Maatuk, and Aljawarneh (2016), the usability is evaluated in a web-based transactional system for an airline; the applied technique was usability tests with users. As reported by the study, the results were satisfactory, allowing to identify weaknesses and spaces in the system that require recommended solutions for them.

On the other hand, Grigera, Alejandra, Rivera, and Rossi (2016), propose to evaluate the usability with an automatic procedure in web applications in production, the adopted method was usability tests with users, arguing that the information collected belongs to real data of use and experiences of users. The research is similar to this project, because it evaluates usability in web applications. However, it differs in the applied technique. A very important aspect of the research is the use of heuristics for the automatic analysis of user interactions. Other conclusion is that the approach used has some limitations, since there are usability problems that require human reasoning; which becomes as a reference, to include a previous sight of the evaluator through the results of the characterization of web applications.

The work by Jimenez, Lozada, and Rosas (2016), proposed to justify the need to formalize a process for specific development in usability heuristics; and the documentary inspection of 65 articles related to the technique was done. In summary, Nielsen's heuristics were the basis for most of the studies on usability evaluation; and it was possible to demonstrate that there are no previous actions that provide information to apply a subjective technique.

In the study conducted by Paz, Villanueva, and Pow Sang (2015) a web application was evaluated through heuristics and usability test with end users, the intention was to determine a method to find the maximum percentage of usability problems. The researchers manage to conclude that with respect to usability tests with the user, the heuristic evaluation covers

90% of the usability problems found. The similarity with this project is the evaluation of the usability of web applications. However, they focus on evaluating a web application and they do not take into account any previous step to perform the usability evaluation.

Previous investigations described above, show an important investigative path in the evaluation of web usability, some of them using heuristic methods, mainly the one proposed by Nielsen; and usability tests. However, there is a gap in making use of characterization as a preliminary step to the subjective evaluation of web usability.

The characterization of web applications, as a first step to usability evaluation, allows an approach to the software architecture, since it reveals the conditions for software development. According to Martin (2017), the architecture is visualized in the coding, in this case development technologies used are an important part for the implementation of architectural usability strategies, taking into account that some tools are designed to follow certain patterns of development or programming paradigms. The intermediate use of frameworks based on the design pattern Model View-Controller (MVC) could be a factor that decreases the flexibility to implement the tactics and architectures required in usability. Relationship between information architecture and usability is described by Jakob Nielsen (cited by Morville, Rosenfeld, and Arango (2015)) Similarly, the low use of front-end frameworks implies difficulty in implementing usability, according to Katzmaier and Hanneghan (2015) frameworks provide elements based on design patterns, which help to organize the project, and to reuse components. Purpose of this research is not generate a frameworks dependency because architecture is the important fact, however, tools can be configured according to the needs and become constructive factor.

The growth of mobile applications is due to the expansion of smartphones with Android, a Google's operating system. According to Stat Counter (2018), around the world Android has more users than Windows, a desktop operating system. Compared to mobile platforms, Android has 74% of the market; this could show a trend to develop applications for mobile devices, since the exchange of information on the Web will be given in greater quantity through this type of devices.

On the other hand, the number of people involved allows us to observe that it is necessary to motivate and promote team work in students. When grouping by gender, it was confirmed that 20% were women who were involved in the development of web applications, this percentage is close to the one reported by Pardo D. (2016), which according to the Ministry of Education of Colombia, the career of Systems Engineering has a percentage of 26% of women enrolled.

For web applications, a very low percentage of applications in production was found, or available to access from a web client, it is considered as an opportunity for improvement. According to Morville, Rosenfeld, and Arango (2015) there are reasons why a web application is no longer used, difficulty in finding information, lack of interactivity or learning, and difficulty in maintaining or modifying the system. Martin (2017) ensures that maintainability and modifiability not only affects the product, but also developers, causing serious economic losses. For these reasons, it is important to look for strategies that increase the percentage of software products in production, to extend the useful lifetime, after they have been developed as degree works. In the same way, practices that improve the quality of this type of products should be encouraged, since they are used in all economic sectors. For Pressman and Maxim (2015), the semantic web will lead to more and more sophisticated

web applications, with access to information in an extraordinary way.

4 Conclusions

The very low level of use of web applications developed as a thesis research work is due to relationship between software architecture, usability and other quality attributes. Usability is applied through architectural strategies, which are identifiable at a very low level in the documentation of the works.

The intermediate use of back-end frameworks based on the MVC design pattern and the low level of use of front-end frameworks is a factor that decreases the flexibility to implement architectural usability tactics in a web application.

The construction of software is a complex activity that requires the effort of a group of people to give an effective and efficient response to the changing and urgent needs generated by organizations. In an intermediate level, some undergraduate works are developed individually, and, for this reason, teamwork should be promoted and encouraged for software development.

5 References

Burak Tekin, F., & Tufekci, A. (2013). A Case Study for the Usability of Public Institutions: Turkish State Meteorological Service web site. Ankara, Turquia.

Centro Virtual de Negocios. (2016). *Cuáles son los sectores económicos de Colombia*. Recovery April, 8 2018, from Centro Virtual de Negocios: https://www.cvn.com.co/cuales-son-los-sectores-economicos-de-colombia/

Elberkawi, EK, El-Firjani, NF-M., Maatuk, AM, & Aljawarneh, SA (2016). Evaluation of Web-based Systems: A New Method and Results. (IEEE, Recopilador) Agadir, Morocco, Libia, Jordania.

Fernandez, A., Insfran, E., & Abrahão, S. (17 de Marzo de 2011). Usability evaluation methods for the web: A systematic mapping study. Valencia, España: 2011 Elsevier.

Grigera, J., Alejandra, G., Rivera, JM, & Rossi, G. (19 de diciembre de 2016). Automatic detection of usability smells in web applications. *Int. J. Human-Computer Studies*. La Plata, Argentina: © 2016 Elsevier.

ISO 25000 Standards. (2018). *Usability*. (ISO/IEC) Recovery March 8, 2017, from Calidad del Producto Software: http://iso25000.com/index.php/en/iso-25000-standards/iso-25010/61-usability

Jakob, N. (2012). *Usability 101: Introduction to Usability*. (N. Jakob, Editor) Recovery February 8, 2018, from NN/g - Nielsen Norman Group: https://www.nngroup.com/articles/usability-101-introduction-to-usability/

Jimenez, C., Lozada, P., & Rosas, P. (2016). Usability Heuristics: A Systematic Review. *IEEE*. Quito, Chimborazo, Ecuador: IEEE Explore.

Katzmaier, A., & Hanneghan, M. (2015). Design Pattern Evaluation of Mobile and Web Based Application Frameworks. *Developments in eSystems Engineering (DeSE).* (I. Explore, Recopilador) Abu Dhabi, United Arab Emirates.

Lund, M., & Sieverthson, H. (2017). Usability Challenges For The Mobile Web An Enterprise Perspective. *Information Systems*. Boras, Suecia. Recovery August 20, 2017, from http://www.diva-portal.org/smash/get/diva2:1088297/FULLTEXT01.pdf

Maat, M., Swaid, S., Krishnan, H., Ghoshal, D., & Ramakrishnan, L. (2018). Usability Heuristic Evaluation of Scientific Data Analysis and Visualization Tools. *Advances in Intelligent Systems and Computing*. Berkley, California, USA: Advances in Usability and User Experience.

Martin, R. (2017). *Clean Architecture: A Craftsman's Guide to Software Structure and Design* (First Edition ed.). USA: Prentice Hall.

Ministerio TIC. (2016). El Gobierno Digital y Las Tendencias Mundiales. 17. (I. Mejia, Ed.) Bogota. Recovery Febraury 18, 2017, from http://www.mintic.gov.co/portal/604/articles-15256_recurso_1.pdf

Morville, P., Rosenfeld, L., & Arango, J. (2015). *Information Architecture for the World Wide Web - Designin for the Web and Beyond* (Fourth Edition ed.). Sebastopol, California, Estados Unidos: O'Reilly Media, Inc.

Nagpal, R., Mehrotra, D., & Kumar Bhatia, P. (2017). The State of Art in Website Usability Evaluation Methods. Uttar Pradesh, India: British Cataloguing in Publication Data.

Ndako, VA, Shehi, IS, Adelowo, SA, & Gbenga, RJ (14 de Mayo de 2017). Towards Designing Mobile Banking User Interfaces for Novice Users. (©. S. 2017, Recopilador) Minna, Nigeria.

Noll, J., Abdur Razzak, M., Bass, J., & Beecham, S. (2017). *A Study of the Scrum Master's Role.*

Ordoñez, C., Hernández Pantoja, G. A., Ordoñez, H., Ordoñez, A., & Cobos, C. (2016). Virtual Community of Practice to potentiate knowledge and skills for building mobile applications in computer science students. En *8th Euro American Conference on Telematics and Information Systems (EATIS).* Cartagena de Indias – Colombia: IEEE.

Ordoñez, C., Ordoñez, H., Ordoñez, A., Cobos, C., & Hernández, G. (2017). Strengthening Competencies for Building Software, Through a Community of Practice. *Advances in Computing. CCC 2017. Communications in Computer and Information Science, vol 735.*, 415-426.

Pardo D., J. (2016). *Se Buscan Ingenieras.* (E. Tiempo, Ed.) Recovery April 10, 2018, from El Tiempo: http://www.eltiempo.com/carrusel/las-mujeres-en-la-ingenieria-en-colombia-38494

Paz, F., Villanueva, D., & Pow Sang, JA (2015). Heuristic Evaluation as a Complement to Usability Testing - A Case Study in Web Domain. *2015 12th International Conference on Information Technology - New Generations.* Lima, Peru: IEEE.

Pressman, R., & Maxim, B. (2015). *Software Engineering - A Practitioner's Approach* (Eighth

Edition ed.). New York, New York, USA: McGraw-Hill Education.

Sanchez, W. (2011). *La usabilidad en Ingeniería de Software: definición y características.* Recovery September 18, 2016, from Redicces Org:http://www.redicces.org.sv/jspui/bitstream/10972/1937/1/2.%20La%20usabilidad%20en%20Ingenieria%20de%20Software-%20definicion%20y%20caracteristicas.pdf

Stat Counter. (2018). *Operating System Market Share Colombia*. Recovery April 9, 2018, from Global Stats: http://gs.statcounter.com/os-market-share/all/colombia/

Taylor & Francis Group. (2014). Computing Handbook - Information Systems and Information Technology (Thirth Edition ed.). (H. Topi, & A. Tucker, Edits.) Waltham, Massachisetts, USA: CRC Press.

A study of stress, displacements and strain in a stress concentrator using analytical calculus and Finite Element Method

bojedag@eafit.edu.co

Brizeida N. Ojeda G.
Mechanical Engineering Department.
EAFIT University
Medellín, Colombia

bojedag@eafit.edu.co

ABSTRACT

A study of stresses, displacements and strain, based on a classic solid mechanic's model, specifically a plate with hole, around which a stresses concentration, is presented. For this purpose, the stresses analysis was carried out in a hole concentrator subjected to tensile. The model's material was ASTM A36. The stresses were analytically calculated, through von Mises' theory. In addition, the analysis of the stresses using the finite element method (FEM) was carried out. Subsequently, displacements and unitary deformation were determined in the part. The results obtained report an error of 8.7% between the stresses of von Mises through analytical calculus and using the FEM.

Keywords: Stresses concentration, Displacements, Unit Strain, Finite Element Method.

Introduction

Engineering designs are increasingly demanding, due to the challenges in which they are incurs in order to increase the efficiency of the results [1], for example the optimization of designs minimizing weight [2], and the use of new materials [3]. To do this, the engineer has seen the need to use computational tools that serve as support to predict the behavior of the designs posed [4]. The vast majority of the computational tools for engineering designs are based on the finite elements method [5]. The presence of holes, steps, slots for cotter pins, spaces for the placement of dowels, cause in the loaded part an increase in the stresses around the area of discontinuity, known as stress concentration [6]. These regions should have paid special attention when designing a mechanical element, which is why this phenomenon has been analyzed theoretically and experimentally; As a result, equations and diagrams have been obtained for different geometry and load types to determine the stresses concentration factors. Materials and methods

1 Methodology

1.1 Initials considerations

To develop the study, a rectangular cross-section plate is selected as a model of analysis, the geometric details of which are shown in Fig. 1., with hole in the center which causes that in the surrounding area is produced the phenomenon of stresses concentrations.

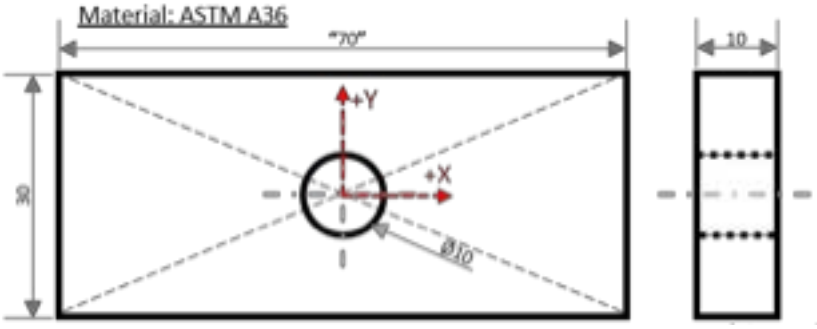


Fig. 1. Analysis Model: Rectangular cross-section plate geometry with stresses concentrations

The plate is supposed to be steel ASTM A36, whose physical Young´s modulus is es E = 2x1011 Pa. According to the configuration presented in the Fig. 1, It is intended to estimate the actual tensions distribution in a stress concentrator, along the Y axis, carrying out the following procedure:

- For the analytical calculation the von Mises theory is chosen together with the Saint Venant principle.
- The piece modeling is done in the SolidWorks software for observation through FEM.
- After analyzing, by both methods, the margin of error is calculated between the results obtained.
- Finally, it is concluded on the results obtained from the analytical theory calculation and computational used, in order to determine the reliability of the results using the FEM in geometries with the presence of stress concentrators.

1.2 Analytical calculus

For the calculation of the stresses in points C, D and E (Fig. 2), three different stresses were taken into account. For the minimum stress, the A-A area is taken, for the intermediate, the area B-B.

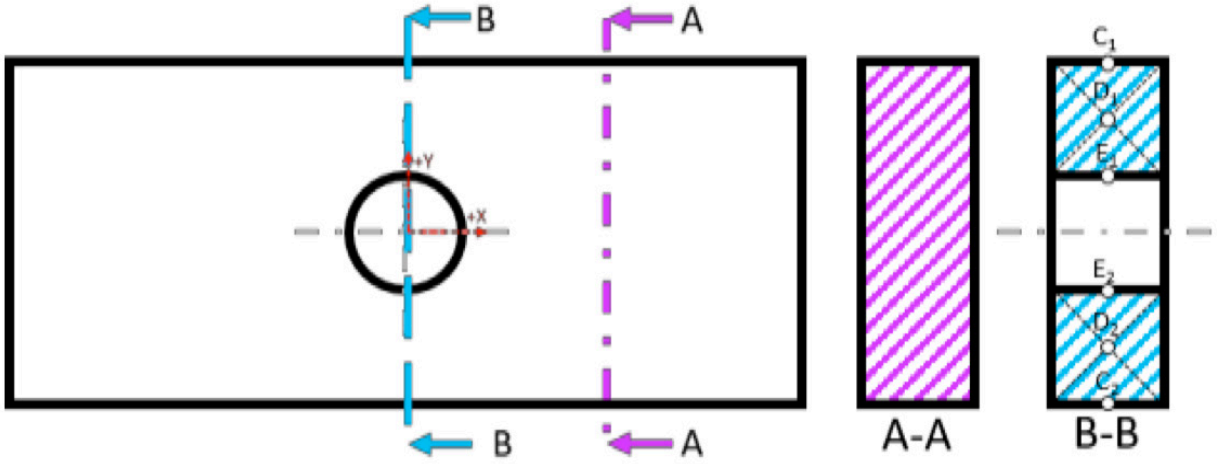


Fig. 2. Sections and points to evaluate on the plate

For the calculation of the stress maximum, the equations 1, 2, 3 and 4 were used.

$$\sigma_0 = \frac{F}{A_{A-A}} \qquad \text{Eq.1}$$

$$\sigma_{Int.} = \frac{F}{A_{B-B}} \qquad \text{Eq. 2}$$

$$K_{tg} = \frac{K_{tn}}{(1 - \frac{\phi}{w})} \qquad \text{Eq.3}$$

$$\sigma_{max} = K_{tg} * \sigma_0 \qquad \text{Ec.4}$$

The previously calculated stresses are used as described in Fig. 3.

The equations 5 and 6 are used for unit strain calculations.

$$\varepsilon_{Max.} = \frac{\sigma_{Max.}}{E} \qquad \text{Eq. 5}$$

$$\delta_{Max.} = L * \varepsilon_{Max.} \qquad \text{Eq. 6}$$

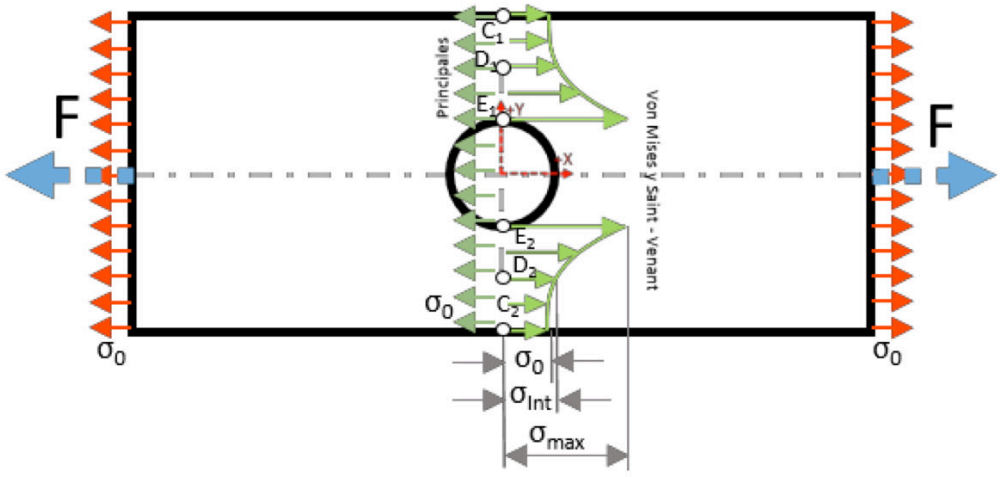


Fig. 3. Von Mises stresses on the plate

1.3 Calculations using FEM

With the software used, the modelling is done with the dimensions of Fig. 1, the only assumed values were the length 70mm and the position of the circle in the center of the rectangle; then extruded to the specified depth. As boundary conditions, a one side of the plate is fixed, and the other a force of 15 kN in tension. In the results of the FEA, it is applied the given material, and later, a tracing of tensions to find the maximum value of exertions by von Mises, then a cut of section is made taking as reference the plane of the side view. In the process 15 nodes are selected in the vertical, in the zones of values of maximum stresses and the respective stress is found. For the cases of displacement and unit strain, the maximum values are found in the same way as the stresses were made. The Table 1 shows the comparison of the results obtained in the stresses with the two methods used, while Table 2, reports the unit strains and Table 3, the displacements, respectively.

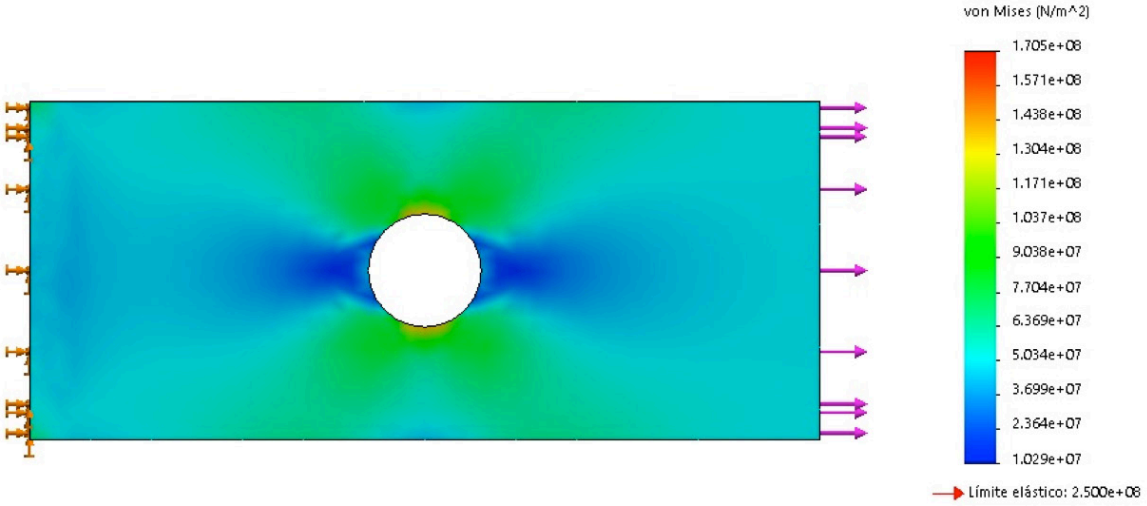


Fig. 4. Von Mises stress using FEM

Table 1. Results comparison and error percentage: Stress

y (mm)	von Mises (FEM) [MPa]	von Mises (Analítico) [MPa]	% Error
15	45,77	50,0	8,5
10	72,42	75,0	3,4
5	170,58	172,5	1,1
-5	170,5	172,5	1,2
-10	72,18	75,0	3,8
-15	45,64	50,0	8,7

Table 2. Results comparison and error percentage: Unit strain

FEM	ANALYTICAL	% Error
5,974E-04	8,625E-04	30,74%

Table 3. Results comparison and error percentage: Displacement

FEM	ANALYTICAL	% Error
0,01967	6,038E-02	67,42%

Diagram A in Fig. 5, the comparison between the two methods used, are showed.

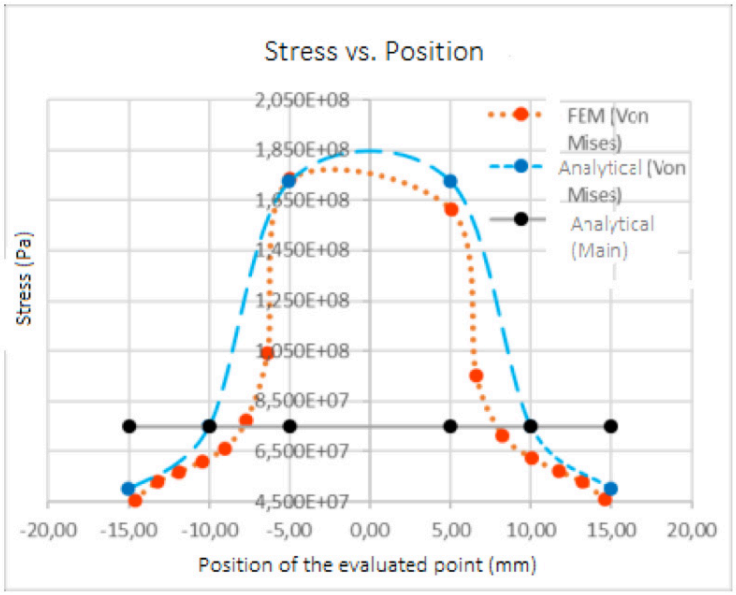


Fig. 5. FEM vs. Analytical

When observing Fig. 4, it can be verified that the stresses calculated by FEM, increase when approaching the center of the piece, this is due to the effects of the load in the central zone, which is the most prone to fail. That is why, as the analytical stress by von Mises took the Saint Venant principle as a reference, it is said that it was the closest to the real value.

With respect to Finite Element Analysis, it can be said that it is better to calculate by this method, because, when taking more nodes to evaluate, it makes a much more precise estimation of the effects of the load on the plate. From the results obtained, it can also be concluded that as the stresses are greater towards the center of the piece, these points should be examined at the time of analyzing it and if the given stress is greater than the stress of creep (to this case Y=2,5x108 Pa)ilt is said to fail. During this analysis, as the maximum stress is lower, it is said that it does not present any failure.

With respect to the gross concentration factor, used to calculate the maximum stress starting from the minimum (Fig. 3), as its value is 3.45, it can be confirmed that the stresses at an end near the applied load are 3.45 times larger than the minimum value.

2. Conclusions

The use of a software based on the finite element method, is a good support for the realization of engineering designs that involve the determination of stress, displacement and strain in complex parts, especially with stress concentrators. Also, the software allows to determine the distribution of tensions in zones with concentrators of stresses with geometric form not defined analytically.

3. References

[1] Camacho, D., Hopper, R., Lin, G., & Myers, B. (1997). An improved method for finite element mesh generation of geometrically complex structures with application to the skullbase. Journal of Biomechanics, 30(10), 1067-1070. Obtenido de https://doi.org/10.1016/S0021-9290(97)00073-0

[2] Asmussen, E., Peutzfeldt, A., & Sahafi, A. (2005). Finite element analysis of stresses in endodontically treated, dowel-restored teeth. The Journal of Prosthetic Dentistry, 94(4), 321-329. Obtenido de https://doi.org/10.1016/j.prosdent.2005.07.003

[3] Leclerc, W., Haddad, H., & Guessasma, M. (2019). DEM-FEM coupling method to simulate thermally induced stresses and local damage in composite materials. International Journal of Solids and Structures, 160(15), 276-292. Obtenido de https://doi.org/10.1016/j.ijsolstr.2018.10.030

[4] Metan, S., Krishna, P., & Mohankumar, G. (2014). FEM Model an Effective Tool to Evaluate Von Mises Stresses in Shoulder Joint and Muscles for Adduction and Abduction. Procedia Materials Science, 2090-2098.

[5] Preciado, A., & Sperbeck, S. (2019). Failure analysis and performance of compact and slender carved stone walls under compression and seismic loading by the FEM approach. Engineering Failure Analysis, 96, 508-524. Obtenido de https://doi.org/10.1016/j.engfailanal.2018.11.009

[6] Budynas, R., & Nisbett, K. (2015). Shigley's Mechanical Engineering Design. New York: Mc Graw Hil.

Innovation

Development

Engineering

Applied

Science

FACULTAD DE INGENIERÍA EN CIENCIAS APLICADAS

Supply chain optimization by means of product packaging reuse: a case study

Cecilia.galvez23@gmail.com
idherrera@utn.edu.ec
christian.diaz02@epn.edu.ec

Martha C. Gálvez Tapia [1], Israel D. Herrera-Granda[2] and Christian S. Díaz Cajas[3]
[1] Facultad de Ciencias Naturales y Matemáticas, Escuela Superior Politécnica del Litoral, Campus Gustavo Galindo - km. 30.5 vía perimetral Guayaquil, Ecuador
[2] Facultad de Ingeniería en Ciencias Aplicadas, Universidad Técnica del Norte, Av. 17 de Julio, 5-21, y Gral. José María Cordova Ibarra, Ecuador
[3] Escuela de Formación de Tecnólogos, Escuela Politécnica Nacional, Av. Ladrón de Guevara E11-253, Quito, Ecuador

Cecilia.galvez23@gmail.com, idherrera@utn.edu.ec, christian.diaz02@epn.edu.ec

ABSTRACT

The current work shows the application of reverse logistics in the supply chain of a multinational company wich distributes mass consumption products focused on re-utilization of packaging boxes, and increase of storage capacity and product transportation. Based on the methodologies developed, a logical framework is implemented in a multinational company of consumer products centered on the Out Of The Box, Project Manajement Body of Knowledge and Lean Six Sigma methodologies. A part of this logical framework has been successfully implemented in: Brazil, Mexico, Argentina and Colombia. The execution includes the following stages: identifying which products or stock keeping units in the warehouse can be standardized, designing packaging prototypes of packages or boxes that can be reused from the manufacturers of raw materials until the finished product and that can be used for reuse in packaging of other similar products, quality tests are executed in order to ensure the strength and longevity of the boxes. As a result of its implementation, an increase of financial efficiency was obtained for the company in case, , reducing its logistics costs in comparison with the sales revenues by around 8%, as well as a significant improving of its environmental management .

Keywords: Reverse logistics, Packing boxes, Transportation, Supplier integration, Manufacturing centers, Supply chain.

Introduction

Reverse logistics is a subsystem of the Supply Chain (SC) that is poorly exploited in Ecuador and the latin american networks. Within the context we can mention the low integration of suppliers for the efficient management of their supply and distribution networks, this is a consequence of the existing logistics platform, the priority use of unimodal transport, the concentration of road transport, the influence of Customs regulations, the existence of several suppliers with insufficient production capacity scattered in several locations within small territories and the absence of studies on operational productivity initiatives[1], [2], [3], [4], [5].

From academic point of view, at local and regional level there are very few studies similar to the present, being the work published in 2018 by Rodriguez one of them who evidence a successful implementation of the method for packaging management in the SC[6].

The project complexity was increased since the analyzed company has more than 7000 Stock Keeping Units (SKU), of which 30% of the share are innovations, it means non-regular sale products. Taking advantage of this information, it is identified which products are susceptible to be included in the project, taking great care of the logistics and packaging selection.

Once it has been established, the design and improvement of the ideal packaging to be used in the SC netwok, for this purpose, it is required to consider several variables such as the percentage of occupation of products in the boxes, the productivity in line of shipments and transportation lines, the density of the warehouse , vehicle occupancy, operating costs, productivity and ergonomics.

The project design is composed of five programs wich are aligned to each strategic partner scope of the value chain as well as to the key processes. All of them are described as follows.

Internal Manufacturing: Products manufactured in the main plants located in Latin America and the Distribution Centers (DC) of each country in which brand Company has presence.

Manufacturing Centers (CM's): Some places where the company has a product manufacturing flow through toll manufacturing systems.

Raw Material and Component Suppliers: Deliver several materials in a continuous supplying flow of supply, necessary to meet production in own factories and in toll manufacturing systems (contract manufacturing CM's).

Finished product suppliers: Supply continuous and direct DC´s with finished products, ready for sale.

Clients: Corresponds to the product flows which are sent from the Distribution Centers of the company to customers.

Based on previous studies and the integration of the key partners described above, the company organizes its business logistics based on the System: Plan, Operate and Control (PAC) [5], [7],[8]. Therefore, it is identified several opportunities to maximize its business, which are mentioned in below lines.

Reuse of wrapping elements, packaging and pallets; Redesign and standardization of packaging or boxes.

Increase of productivity in storage capacity with the optimization of the stacking pattern of each pallet based on the use of the new box.

Transportation Productivity as a consequence of the increase of load capacity using double stack systems, reducing the amount of trips and the implementation of round trips "round trip" that takes advantage of the efficient use of the fleet of trucks in the frecuent routes. For instance, maritime ports to DC´s and their returns to the manufacturing centers, They are known as closed transport circuits, which reduce transportation costs due to scale economies. The PAC system is illustrated in Fig. 1.

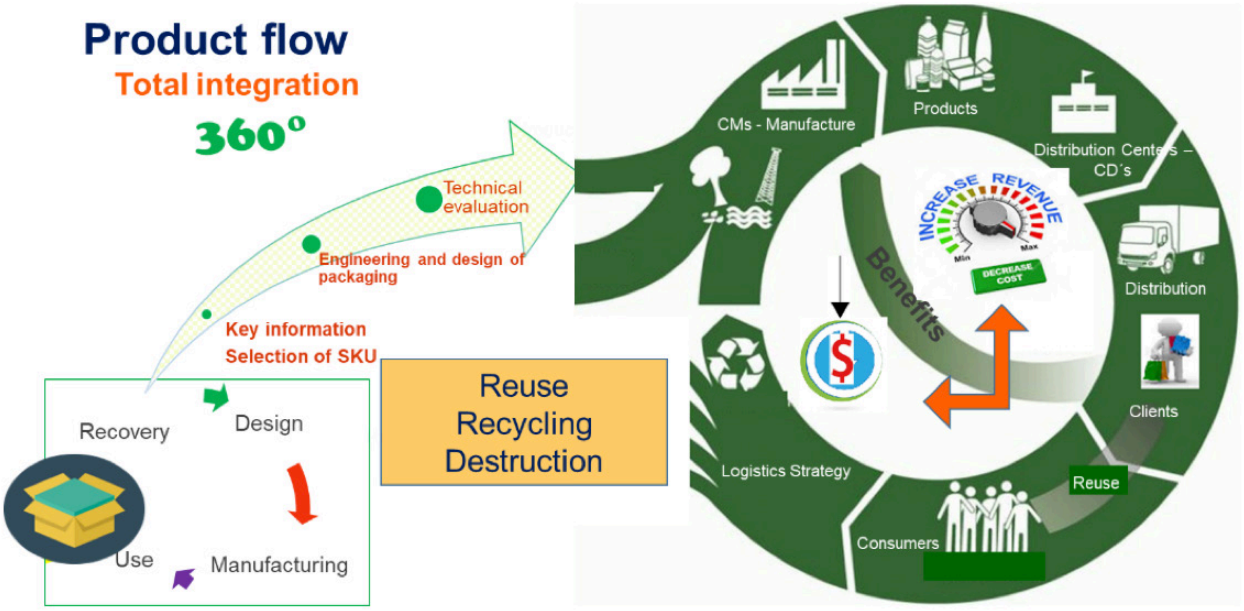


Fig. 1. Strategic business logistics concept- PAC[8]

The objective of this paper is to show a case study of a company in our region that, based on the proper management of its packaging, reduces its operating costs, which can be replicated in other local companies.

1 Materials and Methods

The project was designed using key approaches for the development of projects such as: Lean Six Sigma, Project Manajement Body of Knowledge (PMBOK) [9], and Out Of The Box (OTB). It is important to mention that the OTB methodology is suitable for any market and business, where it is possible to realize financial, operational and environmental benefits In terms of design and packaging development, the company was supported by experts in packaging engineering who used specialized software such as Maxload [10] and TOPs [11]. These softwares will be applied only on the standardized boxes through paretto analysis. A summary of the stages of the project is shown in Fig. 2.

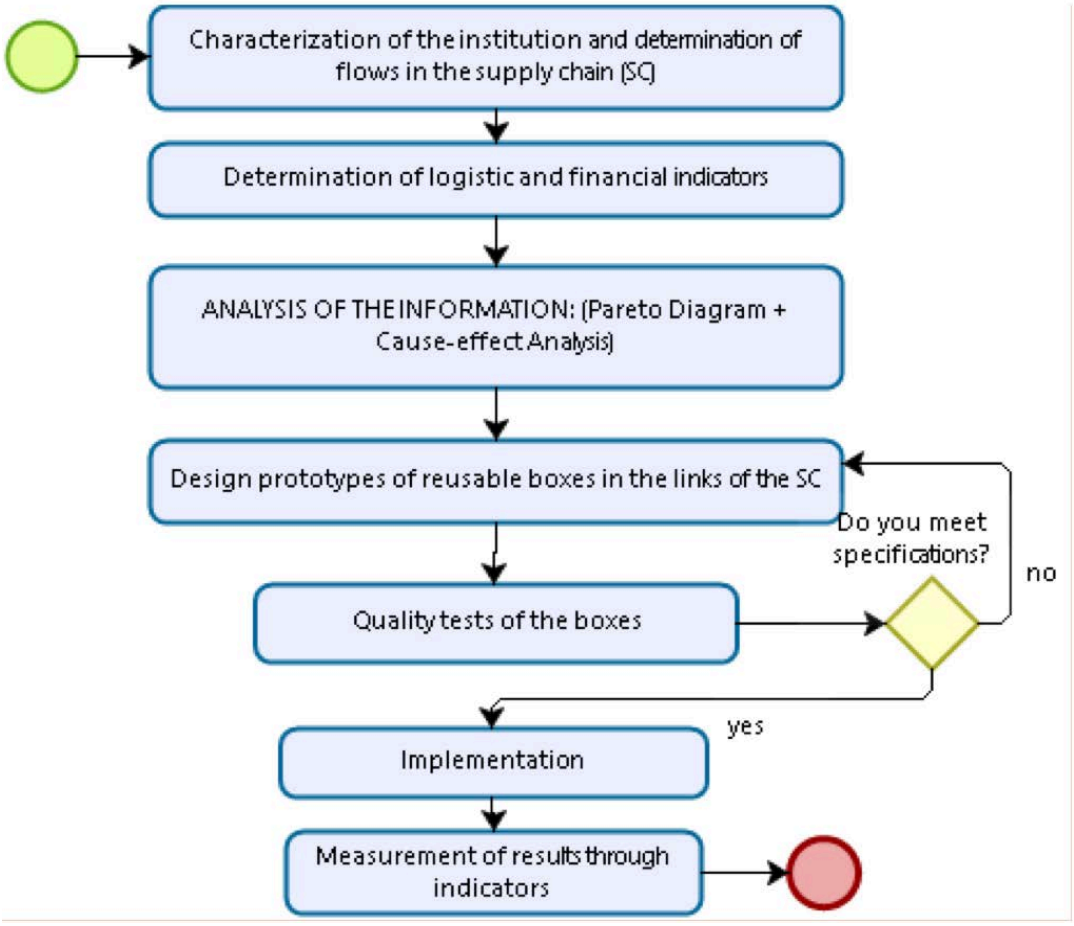


Fig. 2. Stages of the project to optimize the use of packaging.

1.1 Characterization of the Supply Chain

The analyzed company is a multinational that produces and distributes mass consumption products with presence in more than 10 countries in Latin America, and moves more than 83.000 tons of cargo with more than 1000 routes and approximately 26.000 transactions will be done in order to connect 5 factories with 11 distribution centers (DC´s) which have to supply to around in total 100 delivery points. The present work is focused in the oerations of Colombia, Peru and Ecuador (CPE cluster). At the level of the CPE cluster, around 7000

SKUs are handled.

Within the characterization of the SC of the mentioned company, the significant entities that interacts have to be defined pursuing the purpose of the improvement of the use of packaging. For this, the Suppliers, Inputs, Process, Outputs, and Customers (SIPOC) table was used, as shown in Table 1.

Suppliers (S)	Inputs (I)	Process (P)	Output (O)	Clients (C)
• Manufacturing centers.	• Redefinition of new manufacturing packaging standard.	• Management of boxes and implementation of reuse cycles.	• Implementation of 8 to 10 cases of manufacturing.	• Clúster CPE
• Material suppliers.	• Definition of method of transporting product to DC´s.	• Implementation of double stack in trips.	• Pallet with maximum height of 1.15m and 1.35m maximum weight 900kg.	
• Finished product suppliers.			• Boxes weighing less than 12 kg	
			• Reduction of corrugated expense. • Reduction of transport freight. • Storage optimization.	

The data collection and SC flow calculation allowed establishing the quantity of boxes that flows within the SC, as an improvement strategy is established the initial operational flow which is existing before the project implemention, as it is shown in Fig.3.

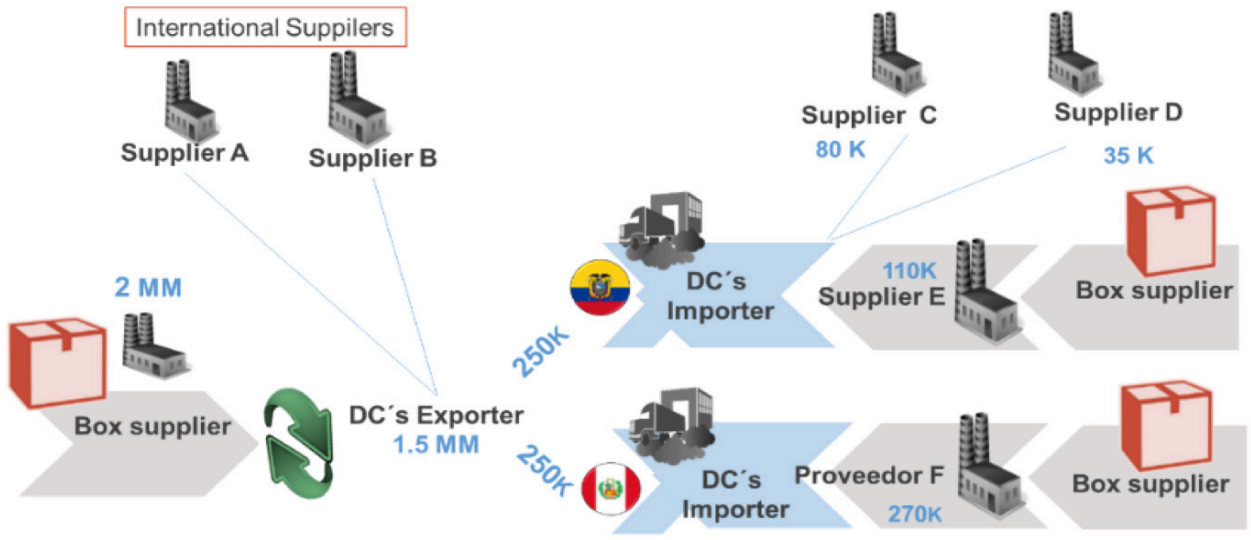


Fig. 3. Initial operating flow

Analysis of information

Once the information concerning of the SKU´s of the company was obtained, a Paretto analysis was carried out regarding common-characteristics references (SKU), so that either is possible to standardize several SKUs in a common-size single box or standardize a box that can be used in most of the stores. It means it can be used in primary storage and can also be reused to pack the products manufactured in the manufacturing centers or poll manufacturing plants as well as in the distribution of mentioned products to the customers.

Furthermore, the mentioned common-size box can be used in the supply, so it can be used either for suppliers of own plants or for materials manufacturers; therefore, guaranteeing the inclusion of all the SC links, as shown in Fig. 4.

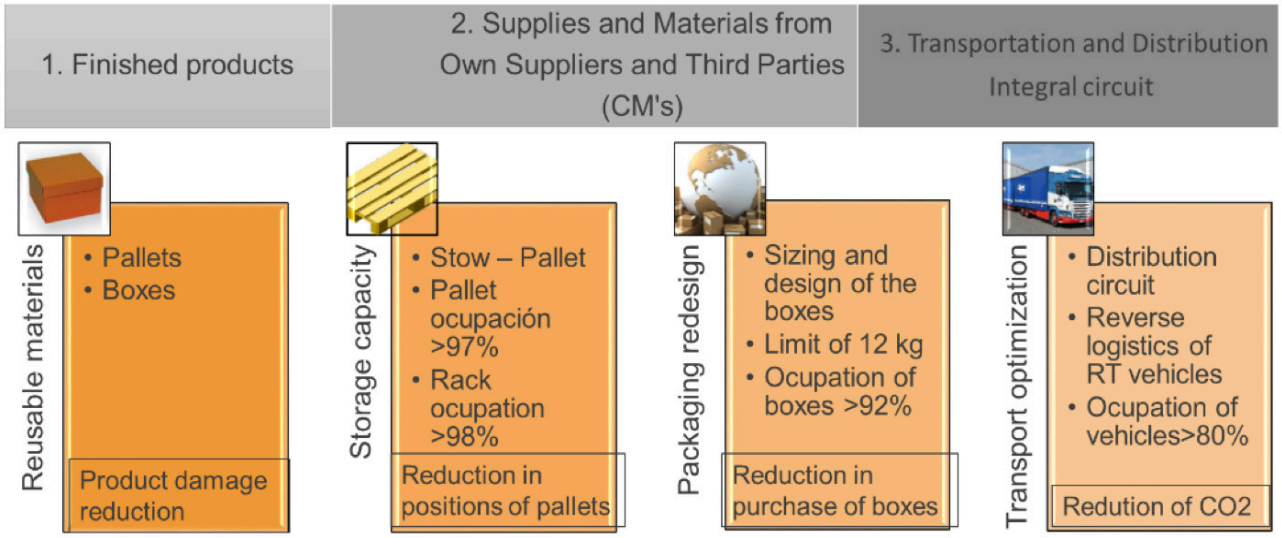


Fig. 4. Identification of opportunities for reuse of packaging in the supply chain (SC)

Another analytical tool used to determine the reasons for incurring high packing costs was the Cause-Effect diagram or Ishikawa diagram[12], which allowed to identify the root causes in the management of the company's packaging, as shown in Fig. 5.

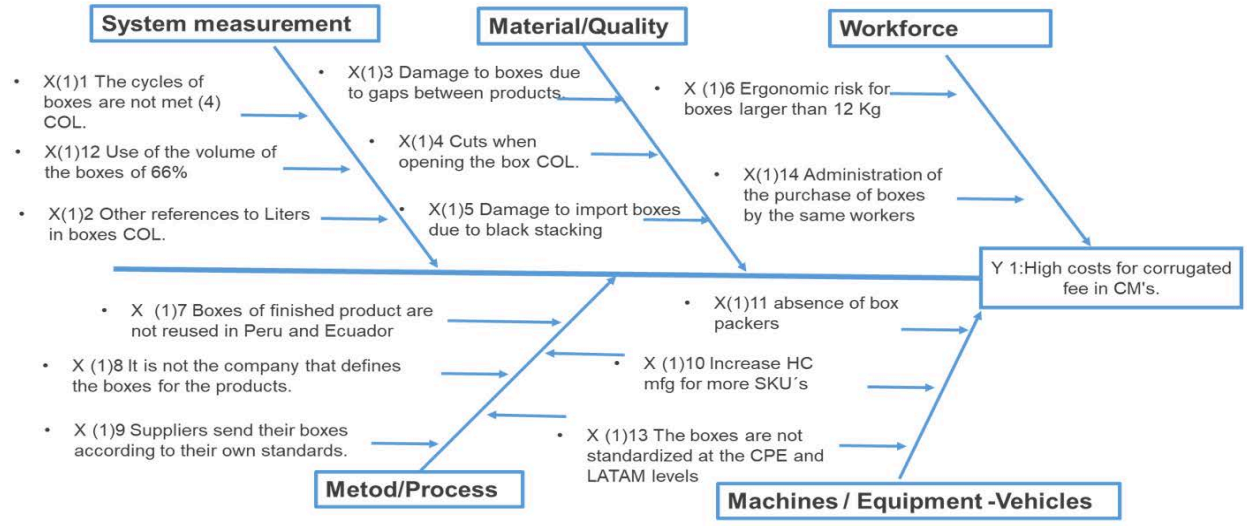


Fig. 5. Cause effect diagram to determine the reasons for high packing costs

1.2 Proposed execution model

The input and output operating volumes in the year 2017 were taken as information data, and a set of operations was analyzed in Colombia, Peru and Ecuador (CPE cluster). Additionally, an analysis, testing of the current boxes was required as well as a measurement of the occupation in the pallets and warehouse in order to determine densities and optimal designs of the boxes finally.

To have a successful implementation of the project, the standards recommended by the PMBOK guide were followed [13]. For the adequate management of projects, a multidisciplinary work team was also available that involved several collaborators of the CPE cluster.

By means of the project implementation and through the participation of all project members, the company's SC flows could be redesigned, so that the strategic inclusion of a regional plant responsible for supplying the DC´s located in Colombia and in Ecuador. It was also possible to establish that said regional plant is in charge of working directly with a specialized supplier of standardized boxes upstream of the SC; therefore, at the level the mentioned standardized boxes can be reused, as shown in Fig. 6.

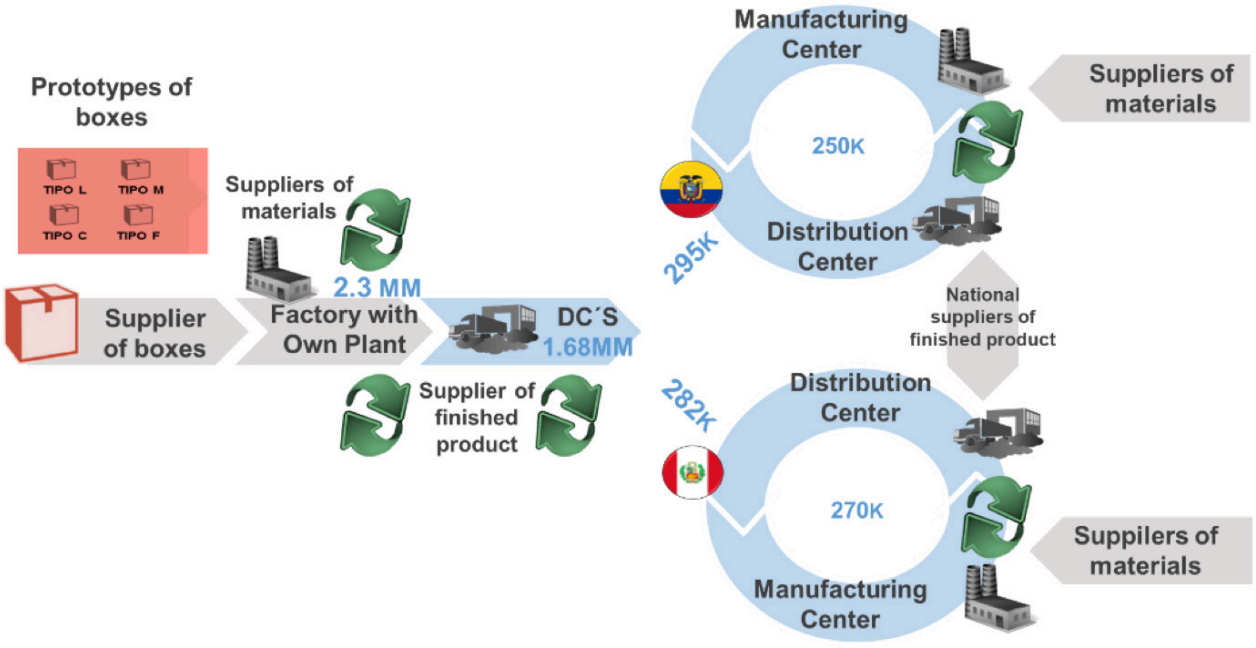


Fig. 6. Proposed operating flow.

Environmental impact caused by the use of boxes

One of the main contributions of the reverse logistics studies is the analysis of the use of packaging; the aim was to reuse the boxes used as packaging for the products, otherwise they would be deposited in the environment, causing a negative environmental impact.

Design of new re-usable boxes in the SC

Once the dimensions of the standardized boxes were determined to be used in the studied company SC, then a suitable design stage must be passed by means of a Computer Aided Design (CAD) software TOP [14]. The use of higher quality materials, and the execution of quality tests on the boxes are additional key approaches in order to maximize the life cycle of a box with standardized measures.

The study company considers that the box must fulfill the function of protecting the integrity of the product from the company to the client; however, it is not compulsory that the box must be used only once, it must be reused as many times as its design he allows it. To this end, technologies were also implemented to protect the integrity of the boxes, such as the use of elastic bands on DC´s, the correct handling and classification of boxes by type. As shown in Fig. 7.

Fig. 7. Strategies for the re-use of boxes

1.3 Control of project execution

In order to perform a proper monitoring and control of the project execution, the Lean Six Sigma methodology was used as well as the Project charter recommended by the PM-BOK was also used. Undoubtedly, all of them increased the organizational level and the control of the activities that were carried out. As shown in Fig. 8.

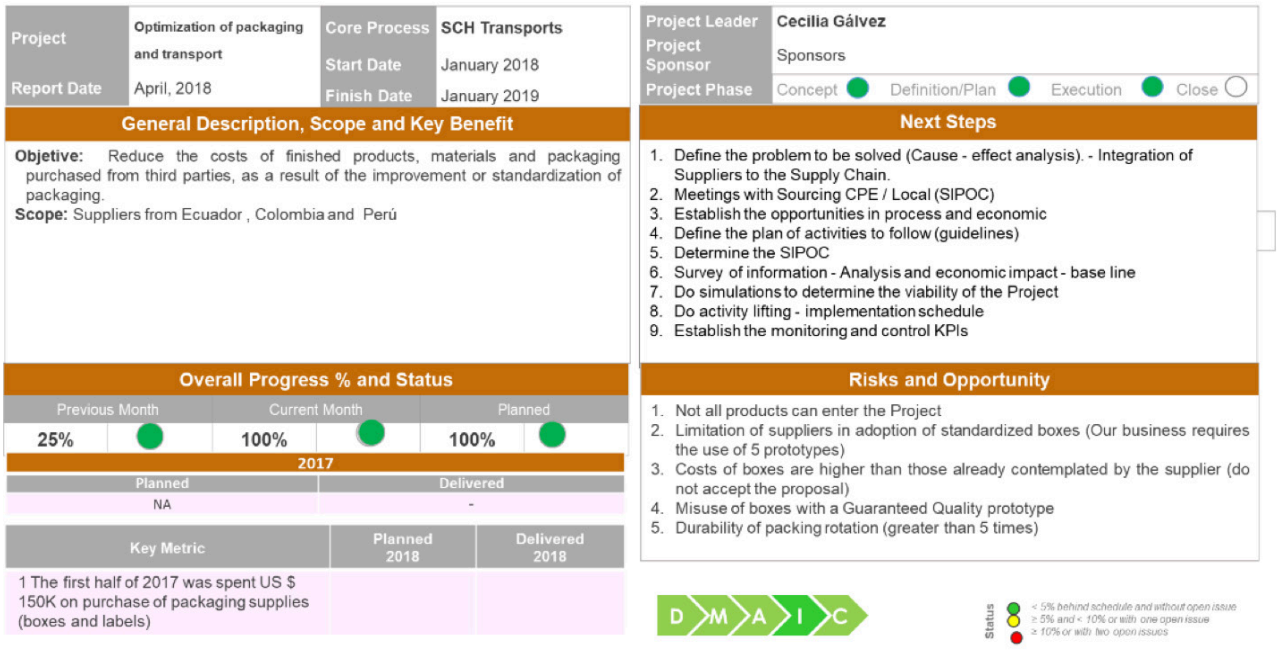


Fig. 8. Project Charter

2 Results and Discussion

Through the execution of the project it was possible to redesign the operational flow in the SC of the studied company, upgrading the SC work with fewer quantity of box suppliers and mainly reusing these in the SC which is a strategic strength in the organization.

By means of the packaging standardization used in the SC for the CPE cluster, a significant growth in the productivity cause the use of the wrapping and shipping materials was obtained, going from 66% to 92%. An increase in the utilization of pallets in which the boxes of products are stacked from 76% to 97%.

However, the main benefit and contribution as part of the Social and Global Responsibility is the reduction of 45% in the use of cardboard boxes generating less environmental pollution and the consequent decrease of approximately 100 tons of wood from trees that is required for the production of boxes and pallets

In addition, with the execution of the OTB project, there were notable increments in vehicle occupancy and reduction of freight fees that positively influences the operating costs of the company's logistics operations, as shown in Table 2

Table 2. Indicators of packaging management

Indicator	Initially	Implementing OTB	Difference
Quantity of pallets - supplier of finished product	65.554	68.136	+4%
Amount of boxes	3,5 MM	3,8 MM	+9,6%
Variety of boxes in Colombia	4	10	+150%
Variety of boxes in CPE	12	10	-16,66%
Platform height	1,35m	1,45m	+7,04%
Occupation of the boxes	66%	92%	+26%
Pallet occupation	85%	97%	+12%
Vehicle occupancy	42%	80%	+38%
Weight of the box (AVG)	12,1 Kg	9,9 Kg	-18,8%
Weight of the platform (AVG)	690 Kg	676 Kg	-2,02%
Units/box (AVG)	41	33	-19,5%
Freights (Factory- DC´s)	8	5	-37,5%
Freights (Peru/Ecuador-cm)	3 Ecuador 5 Perú	2 Ecuador 3 Perú	-37,5%

By means of financial impact calculation in the implementation of the OTB project through an analysis of sales, general and administrative expenses (SG & A) for 2017, an effective reduction of 4% of the total costs of the SC in the CPE cluster could be determined; particularly, in Ecuador, savings are 3%. As shown in Table 3.

Table 3. Calculation of the financial impact

Consolidation	SC area	(Fav) / Unfav. In USD MM					
Concept	Picking &Logistic	Q1	Q2	Q3	Q4	FY	YR 2
Corrugate Cost CM´s Fee PPV	Packaging	-0,14	-0,14	-0,14	-0,14	-0,58	-0,58
Freight Cost enterprise CM´s to Branch	Transportation	-0,03	-0,03	-0,03	-0,03	-0,14	-0,14
Corrugate Cost	Packaging	0,19	0,04	0,04	0,04	0,29	0,12
Freight Cost Corrugate	Transportation	0,01	0,01	0,01	0,01	0,04	0,04
Adittional resource for box reuse	Packaging	0,02	0,01	0,01	0,01	0,06	0,06
Total Benefit		0,03	-0,12	-0,12	-0,12	-0,33	-0,50
Reracking positions 3PL optimization	Warehouse	-0,01	-0,008	-0,008	-0,008	-0,043	-0,043
Reracking Branch CPE	Warehouse	0,01	0,00	0,00	0,00	0,018	0,018
Resources for reuse process	Maintenance	0,008	0,00	0,00	0,00	0,008	0,008
Total SG&A		**0,00**	**-0,01**	**-0,01**	**-0,01**	**-0,023**	**-0,018**
Total Saving (-)/Over cost(+)		**0,029**	**-0,126**	**-0,127**	**-0,128**	**-0,348**	**-0,514**
Total Cost Avoidance		**0,03**	**-0,13**	**-0,13**	**-0,13**	**-0,071**	**-0,071**

3 Conclusions

This project is appropriate to be applied in any business model and product type, it is sufficient to make a deep observation of the existing opportunities according to the market in which the reverse logistics is executed.

Having a good information system with highly reliable data and the last year of operation, especially of input and output of products, volumes of purchases of packaging and packaging materials as well as transport and distribution costs, and indicators of financial costs and expenses are keys to a robust decision making.

It must enclose a good management system by processes of the company, mainly in the area of operations, always keeping in mind the particularities of the business, regulatory and standardized procedure aspects as well as the application of total ethics to ensure the sustainability of the results in time.

For the implementation of this type of projects, one must have an open mind and a total predisposition to face new changes and challenges in business operations. Ideally the information should be raised by reliable information systems and integrated software such as JDE, SAP, etc.

The implementation of this project was possible with the use of project management methodologies PMBOK, Lean Six Sigma and OTB; however, it is essential that initially all company processes are clearly defined and updated for all company employees, that is, all those involved must know the business to their suppliers, the regulations and tax and legal regulations. In addition, the project must be aligned with the institutions' policies and values.

Finally, regarding the scientific contribution of this work, we can mention the establishment of a sequential methodology to implement a project to optimize the use of packaging in line with new environmental policies that minimize the emissions of waste in companies. This model in question can be implemented in multinational and regional companies thus contributing to the sustainability of the supply chain companies. Indeed, the model is presented for the proper management of packaging in multinational or regional companies that combines other traditionally used methodologies such as PMBOK, Six-Sigma and OTB.

References

1. *Dekker, R., Fleischmann, M., Inderfurth, K., Van Wassenhove, L.N.: Quantitative Models for Reverse Logistics Decision Making. In: Reverse Logistics (2004)*

2. *Bowersox, D.J., Closs, D.J., Cooper, M.B.: Administration and logistics in the supply chain. McGraw-Hill, (2007)*

3. *Elmas, G., Erdoğmuş, F.: The importance of reverse logistics. Int. J. Bus. Manag. Stud. 3, 161–171 (2011)*

4. *Closs, D.J., Savitskie, K.: Internal and external logistics information technology integration. Int. J. Logist. Manag. 14, 63–76 (2003)*

5. *Armijos, M.: Strategic Planning Manual. , Brasilia (2011)*

6. *Rodrigues, R.: Metodología "Out of the Box" para la optimización de la cadena de suministro. Caso Avon - Zonalogística, https://www.zonalogistica.com/metodologia-out-of-the-box-para-la-optimizacion-de-la-cadena-de-suministro-caso-avon/*

7. *Geral, E.M.: ACORDO SETORIAL. http://file.abiplast.org.br/download/links/pnrs_e_o_acordo_setorial_de_embalagens.pdf, Brasil (2017)*

8. *ABAD: National Plan of Solid Residues, https://newtrade.com.br/logistica/abad-promove-palestra-gratuita-sobre-o-plano-nacional-de-residuos-solidos/*

9. *Larson, E.W., Gray, C.F.: A Guide to the Project Management Body of Knowledge: PMBOK (®) Guide. Presented at the (2015)*

10. *CHEN, M., DAI, J.: MaxLoad Pro: Cargo Load Configuration Software [J]. Packag. Eng. 6, 85 (2004)*

11. *WANG, Y., KONG, F., LIU, M., WEN, R., JI, H.: Research on Application of TOPS Pro Software in Optimum Packaging Design for Liquid Milk [J]. Packag. Eng. 10, 58 (2008)*

12. *Ivanov, D., Tsipoulanidis, A., Schönberger, J.: Global Supply Chain and Operations Management. Springer Berlin Heidelberg, Berlin (2017)*

13. *Rose, K.H., Indelicato, G.: Book Review: A Guide to the Project Management Body of Knowledge (PMBOK® Guide), Fourth Edition. Proj. Manag. J. 40, 104–104 (2009). doi:10.1002/pmj.20125*

14. *TOPS Software Corporation: TOPS Pro and MaxLoad Pro software for package design, pallet optimization and load optimization planning., http://www.topseng.com/*

Security in smart objects, a general view at the physical and logical level

fgcuzme@utn.edu.ec
walter.zambrano@fci.edu.ec
wilner.cuenca@fci.edu.ec
cmoreira@espam.edu.ec
edison.almeida@live.uleam.edu.ec

Fabián Cuzme-Rodríguez[1], Walter Zambrano-Romero[2], Cesar Moreira-Zambrano[3], Edison Almeida-Zambrano[4] and Wilner Cuenca Álaba[5]
[1]Universaidad Técnica del Norte, Facultad de Ingeniería en Ciencias Aplicadas, Carrera de Telecomunicaciones, Av. 17 de Julio y General José María Córdova, Ecuador, Ibarra,
[2]Universidad Técnica de Manabí, [3]Escuela Superior Politécnica Agropecuaria de Manabí MFL,
[4]Universidad Laica Eloy Alfaro de Manabí,
fgcuzme@utn.edu.ec, {walter.zambrano, wilner.cuenca}@fci.edu.ec, cmoreira@espam.edu.ec, edison.almeida@live.uleam.edu.ec

ABSTRACT

In this research we addressed an issue of big importance with regard to information and computer science security. Within this area, we know that security is framed within the confidentiality, integrity and availability (CIA) triangle, which refers to confidentiality, integrity and availability of information or objects connected to the Internet, a subject that should be treated with great awareness. We live in an interconnected world where most of devices at home, businesses, industries, organizations, and cities are connected to the Internet. Within that environment, these objects are fulfilling some functionality that facilitates the lives of each individual, although making them somehow dependent on this technology with a high degree of risk to which they are exposed. This study aimed to explain and demonstrate that most of electronic devices or intelligent objects that are developed, locally or overseas, do not have a proper design with regard to making information security a first priority, then, proposing a guiding scheme that allows an adequate development cycle of intelligent objects. The study concluded that we are not 100% safe, as well as cyber-attacks will continue to evolve, so the conception of information security will have to evolve as well.

Keywords: cyber-attack, intelligent object, interconnected, information security, IT security.

Introduction

Information security dates back to ancient times when information was encrypted so that if it were intercepted it would be difficult to understand, but, with the advancement of technology, these traditional methods of security had to be changed to make them more secure, due to hackers who wanted to obtain information or access information systems used the vulnerabilities found in connected environments, both in hardware and software.

When talking about safety in objects, we must settle the following question: What is an object? According to the [1], an object is considered as a thing that defines it as "Inanimate object, as opposed to living being.", so it is important to state that once components such as: sensors or actuators, connectivity, information collection platform, the Internet and the interface to display information are added, we would no longer have an inanimate object, but a device that interacts through the aforementioned components to perform some specific activity for which it was designed [2].

It is important to note that we can find some terms about smart objects that are discussed in this research, one of them is IoT (Internet of Things), a term introduced by Kevin Ashton in 2009, Professor at MIT at that time, [3], although according to Ashton the term was already spoken internally in research groups since 1999. [4], refers to a Verizon publication that pointed out that social networking technologies, as well as the exponential growth of internet applications and services, will lead to the development of the next generation of internet services that will be pervasive, ubiquitous and will affect all aspects of our lives. The number of IoT devices is expected to reach more than 50 billion by 2020.

It is imperative to include the term IoT, since we can associate it with objects or things, where we can give a specific functionality to a simple object to turn it into a device with added value, even more, we can aim solutions to areas such as medicine, industries, sports, education, leisure, work, among others, where each one contributes significantly to people´s daily basis. However, here comes another question: How safe is our private information?

Pacheco & Hariri, 2016, also states that integration of physical and cybernetic systems, as well as human behaviors and interactions (for instance, producers, consumers, and

attackers) will drastically increase the vulnerability and the attack surface of ecosystems of interdependent infrastructure. Smart homes and smart buildings, common architectures that for a long time were isolated, are now being added supervisory control and data acquisition (SCADA) systems. Where these infrastructures are easy targets for cybercriminals, since their structures are not designed to be connected to the Internet, as was the case with the Stuxnet attack [5].

Enrique Mafla, expert in computer security, argues that there are no secure computer systems. "They have even hacked into the Central Intelligence Agency (CIA) and the Federal Bureau of Investigation (FBI)," cited by [6], [7], this sets the guidelines that we should not only worry about business environments, where security is treated in a special way, but also to be aware that every day a large number of devices go to market with added functionalities, among the most important it is connectivity and monitoring using an internet connection.

It is important to consider the security of information in accordance with the CIA triangle, that includes three terms: confidentiality, integrity and availability. Where confidentiality refers to give access to authorized user only; integrity is both information and systems are kept intact, that is, without alterations or modifications; and finally, availability states that information and systems remain available at the time they are required [8], [9].

1 Materials and methods

This section addresses the issue of intelligent objects at a physical and logical level, based on a bibliographic research, bearing in mind developments carried out especially within electronics and communication engineering, in addition a specific analysis of physical levels of design and location of the devices where its operation was proposed, as well as at the logical level that corresponds to the functionality of the software that allows the operation of the device.

[4]but it will also interconnect smart buildings, homes, and cities, as well as electrical grids, gas, and water networks, automobiles, airplanes, etc. IoT will lead to the development of a wide range of advanced information services that need to be processed in real-Time and require data centers with large storage and computing power. The integration of IoT with Cloud and Fog Computing can bring not only the required computational power and storage capacity, but they enable IoT services to be pervasive, cost-effective, and can be accessed from anywhere using any device (mobile or stationary, refers to the security framework that shows all levels that should be considered in the infrastructure, as shown in Fig. 1, but it should be noted that this analysis is given for objects that are in first level only, although it is feasible to consider some safety recommendation that fits the other levels as well.

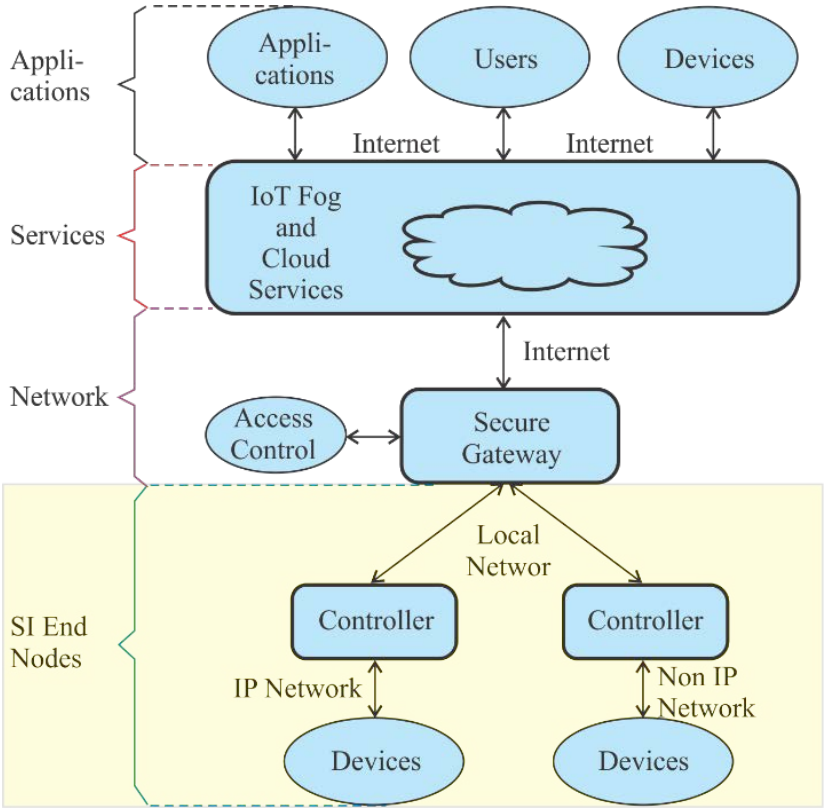


Fig. 1. *Framework for intelligent infrastructures.*

1.1 Physical security

When talking about security at the hardware level we are considering physical access to computers that are commonly connected to the Internet or to an intranet that generate information and is sent through connections to local repositories or to the cloud.

Once a device is part of an interconnected environment, it is important to consider that it could lose its physical security, since it might be located in inhospitable environments and could be reachable by anybody. Attackers could intercept, read or modify information, and could manipulate control systems and modify their functionality [10]. The biggest fear is when users, companies or organizations, use smart objects and they do not take much responsibility about security.

Security at this level is considered as a special way since you cannot compare security levels in hardware in small, medium, and large companies as well as for independent users, where levels of access to objects and data are based on the information they manage, though you should have control to not allow them be manipulated by people outside the interests of users or companies.

Hardware security for intelligent objects should be considered in the structure of products in a way that allows their integrity, furthermore not to admit direct manipulation in case of having access to them. For example, a smart card should have some physical characteristics along with a degree of protection against external agents, so it will not be easily manipulated, for instance, when altering or cloning cards [11]. It is also important to consider providing essential security features, as the following:

ROM booting, verifying security from a very low level, depending on the trusted execution environment where the object is implemented.

Devices that require intensive use of cryptography, hardware implementations can improve performance and extend battery life. However, it is important to understand that ciphers are compatible and they provide a reasonable lifetime for the product.

In circuit design, a possible attack on circuit boards should be considered, that is, its exposure must be taken into account to lessen possible attacks. Whenever possible, circuit boards should not be noticeable.

Interfaces provide access to components of the board, so it can be used to alter several security features. Any interface, console or logic, via USB or serial, must be considered in security contexts. ROM booting often provides a way to download firmware or manipulate the boot process, so that security issues are potentially present.

Components package, the ease of access to memory and the CPU. By selecting certain system options on the chip package, where, for example, the memory is physically located under the CPU, it can complicate hardware attacks that would otherwise be trivial.

Energy administration, it is an important aspect within the hardware platform security, we should consider its resistance depending on storage and capacity processing that will have the object.

1.2 Logical security

Logical security consists on application of barriers and procedures that protect access to data and only those authorized are allowed to access them [12].

The objectives that are proposed will be:

- Restrict access to programs and files.
- Ensure that operators can work without thorough supervision and can not modify programs or files that do not apply.
- Ensure that the correct data, files and programs are used in and by the correct procedure.
- That the information transmitted be received only by the recipient to whom it was sent and not to another.
- That the information received be the same as that which has been transmitted.
- That alternative secondary transmission systems exist between different points.
- That alternative emergency steps be available for transmission of information.

Typically, end users do not take safety into account when they use a system, as security aspects are often ignored. Similarly, these aspects can sometimes be considered a nuisance, because security often goes in the opposite side of comfort and ease of use, in the balance of the design of a system. This is why users can sometimes have a negative image of security, considering it annoying and interrupting their ability to perform a particular task.

In a secure environment, a user can come across with tasks that may be uncomfortable, such as remembering passwords, changing them periodically, etc., actions that can limit the operations that can be performed, as well as the resources to which it is allowed to access [13].

Security flaws of software that can arise based on the analysis done in the document published by Ferrer & Fernández-Sanguino, n.d., on Computer Security and Free Software can be grouped as follows:

- Failures due to unknown errors in software, or known by third hostile entities only.
- Failures due to known errors, but not fixed in the copy in use of the software.
- Failures due to a bad configuration of software, which introduces vulnerabilities in the system.

Each flaw identifies a type of vulnerability. The first one can be attributed to the quality of the code. The second one to the capacity and speed of fixing errors discovered in the code by the provider, as well as the ability of the administrator to receive and install new copies of the updated software. The third type of flaw is due to a lack of software documentation or a lack of adequate training of administrators to make a correct adaptation according to their needs.

The above failures can cause the program to malfunction, so it is necessary to consider the following:

- Algorithms can be implemented incorrectly which can lead to a loss of security, for example, a key generation algorithm that is not based on totally random numbers.
- Services can be designed to, contrary to their specifications, offer undesired functionalities or may compromise the security of the server.
- The necessary measures may not have been taken to ensure the correct handling of the input parameters, by which an external attacker may force the program to perform undesired operations.

There are methodologies for the development of hardware and software, one of the most used is the model in V that includes some stages, used for both types of development, although with regard to software there are other safe development methodologies, OWASP Testing Guide, OSSTMM, ISO 27001, SAFECode, among others[14].

1.3 Developed projects

- Electronic system with artificial vision application for automatic adjustable lighting that provides the optimum amount of light at the focal point of welding in work tables at laboratory scale. Project developed by[15], where a lamp, combined with a number of sensors and actuators as well as the implementation of artificial intelligence, makes the object act on its own to bring light to the user who requires it to weld plates. Here, security is little addressed both physically and logically, because the application does not affect any specific information of great importance.

- Expert system to handle information from sensors for visualization of alerts. Project developed by [16], which is a management platform for the information on forest fire alerts generated by sensors located on the Guayabillas hill. Here, the idea of security changes drastically, because the information handled by sensors and devices is of great importance. A slight approach is made in relation to security both at hardware and software level, where the fact that the computer is chosen as security against vulnerabilities is very subjective, because a computer is considered a little vulnerable. Although the information of the system arrives appropriately, there may be the possibility of manipulation of sensors and the system itself to alter the information that is handled on the platform.

- Design and implementation of a vehicle location and safety prototype system with GPS and GSM communication, based on open software and hardware. Project developed by [17], where no exhaustive security analysis is done so it can be modified at physical level, along with at software level in order to send incorrect location parameters.

These projects as some other developments carried out both locally and overseas are seen to have flaws in their design, although they supply a need to one or more people, the security of those objects is very limited, without considering that there are hackers who are on the lookout to steal information or to use smart devices as points of mass attacks towards other services.

Currently, a variety of intelligent devices are on the rise for every type of need, smart washing machines, intelligent locks, vehicles with automated and intelligent components– which allow users comfort, objects that generate information, among others. At this point, companies and industries that bring solutions in this regard play an important role providing lifelong assistance, and to improving day by day their devices. Although some of these companies may lose customers preference by not being able to offer the security that users could need.

In accordance with this background, we present the SWOT for security in smart objects shown in Table 1.

Table 1. *SWOT of security in smart objects.*

STRENGTHS	WEAKNESSES
Ubiquitous detection. Increase in productivity. Speed and accuracy of the information. Ability to objectively affect the environment of physical world. Improving the quality of life. Experiences solving earlier problems.	Wide attack environment, e.g. data, sensors, systems and devices. Potencial introduction of uncertainty due to high volume of data. Data dissemination through multipl domains. Little awareness of security with connected objects.
OPPORTUNITIES	**THREASTS**
Operational efficiency in real-time. Growth of economic income. New feactures. Steady control for environments at risk. New fields of technology development. Create solutions from earlier problems.	Modality of unanticipated attacks. Little knowledge about IoT security. Thetf or alteration of confidential information. Lask of standards and regulations to create secure IoT objects.

It is important to consider this Table resulting from solutions to prior problems where it has been already clearly identified advantages and disadvantages of any device that solves a need.

2 Results

Fig. 2 shows the components that let us consider a device as an intelligent object, where the first five lower layers are mandatory, and the two upper layers are optional, due to they can be managed from other devices with higher processing, memory and energy capacities.

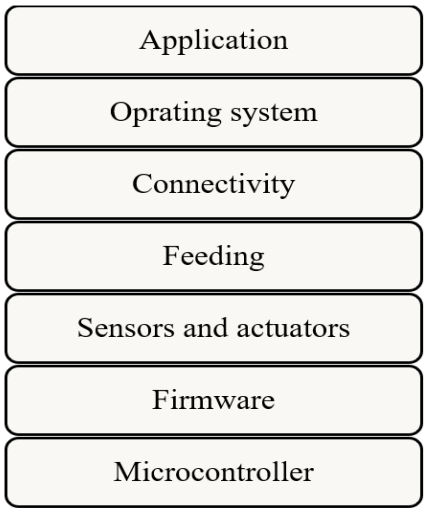


Fig. 2. Components of an intelligent object.

A microcontroller is an integrated circuit or chip that includes in its interior all three functional units of a computer: CPU, memory, and I/O units, that is, it is a complete computer in a single integrated circuit, these are increasingly smaller and not so remarkable.

A firmware is a block of machine instructions for specific purposes, normally recorded in read/write memory (ROM, EEPROM, flash, etc.), which establishes the lowest logic level that controls the electronic circuits of a device of any type.

Sensors collect information about environment, users, or both. For example, light, temperature, movement, location (GPS), etc. Actuators work based on the information gathered by sensors and act in accordance with programmed instructions.

Feeding refers to the battery that objects must have, where there is a serious problem, because the smaller the device is, more limited the energy resources are, therefore, on the one hand, new strategies must be found to reduce energy consumption, or on the other hand, to take advantage of using energy from the environment.

Connectivity is framed in communication protocols that allow devices to interact with others, although, we should look for communication protocols that consumes less energy and also to providing security.

The operating system is a piece of software that will allow us to manage a device according to the functions for which it has been designed, where we can install a greater number of applications to have greater functionality of the object, a good example are smartphones.

It is important to note that all earlier components are integrated, although it is possible to exclude some of them, for instance, to choose just the sensor or the actuator, or ignore the operating system and to program the device at the firmware level, where management will be done from another stronger device to allow us handle a greater number of IoT objects.

Applications are also part of the components of smart objects, even though it will just be for devices with greater processing, memory and energy capacities, to allow them have higher performance based on the requirements that they were designed for.

The components described in this section are usually integrated in a single plate, framing them in a single device, though there would be components that could be excluded in the design of certain devices, to make them less noticeable as is the case of wearables– electronic devices incorporated into some part of our bodies, interacting continuously with us, as wall as other devices in order to perform a specific function, that is, smart watches, sport shoes with built-in GPS, and wristbands that monitor our health, are examples, among others, of this type technology that is increasingly present in our lives.

In addition to presenting the intelligent objects layers, an important security scheme is proposed to consider if a device has an acceptable level of security, as shown in Fig. 3. This scheme also considers some stages, such as storage, hardware and software platforms, however they could be excluded because can be complemented with other stronger devices to offer greater security.

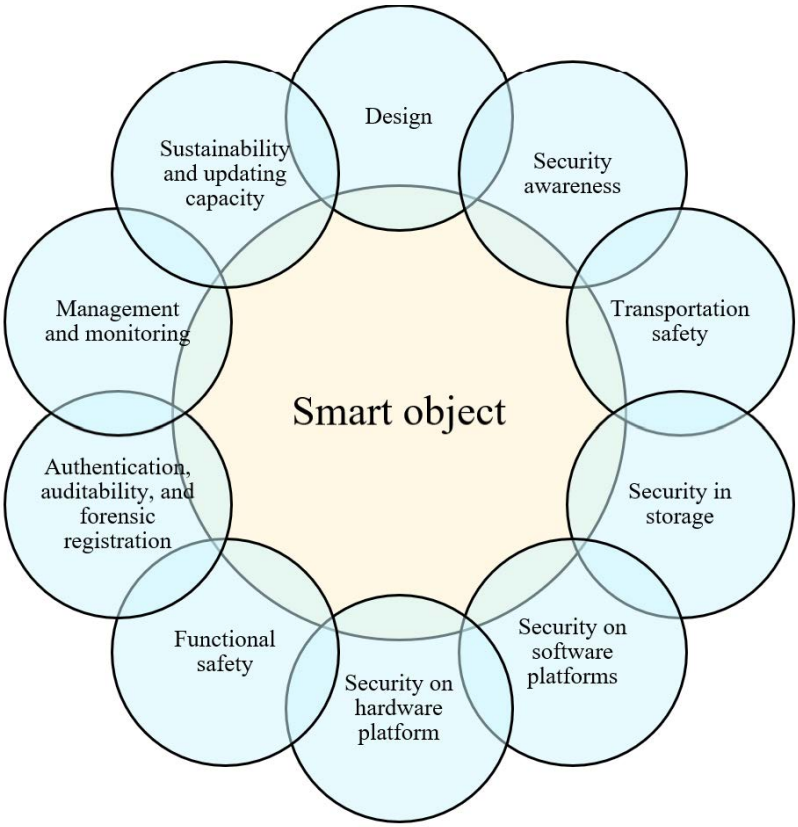


Fig. 3. Security scheme for correct design and implementation of a smart object.

Design, in this initial phase of development a lot of design concepts could de applied, market analysis, competitive analysis, and research support. Here, awareness of security is usually trivial, offering consulting, analysis and advice around high-level concepts, as well as components and technology security capabilities. Although, you could be aware of security assistance regarding the capabilities of competition, and the expected course of market, regulations and legislative forces when it comes to cyber security.

Awareness about safety, there should be considered experiences from the past, records taken during each of the phases, and everything that serves to be conscious of security that devices should have, and take appropriate actions minimizing the risks of vulnerability in objects.

It is possible to apply the ISO 27001 standards, which refers to awareness in a company about security of information, it can also be considered for the physical object as well as the information it manages, that is the security that every component should have to be considered safe.

The security policies and procedures that are considered from now will serve as guidance during the design and implementation of an object for a specific environment, in addition to envisaging possible threats in which they may be compromised.

Also, it should be considered ease of use, fitness factor, energy consumption, and other technological requirements that are important to secure the platform. In addition to people with a security directive, they must be part of this team that participates in the formulation of technical and market requirements, creating a better awareness of the security of objects.

Security in transportation, provide an adequate level of identification, privacy and integrity of the network communication. Understanding how wired or wireless authentication occurs, how credentials are stored, and if they can be relocated into other devices is obviously very important. There are several encryption methods and techniques that you can use, as the hash functions like MD5, SHA-1 or SHA2, among others, but you should also consider processing and memory capacities of objects. In addition to using secure communication channels such as VPNs. Handling IP security protocols that are part of an object security such as IPsec, TLS/SSL, DTLS, HIP, EAP, SSH, in conjunction with the security provided by Wi-fi, 6LowPAN, GSM, and 3G communication protocols, communication security can be improved.

Security in storage, provide the appropriate level of protection of persistent data kept in a device or in a system. Data must be secured when a physical attack occurs. Also the understanding how sensitive data will be secured is vital, both from a perspective of integrity and privacy. We can consider as in the previous argument the encryption for data at rest, then we will protect objects or platforms that stores confidential information not to be so vulnerable to malicious attacks.

Security in software platforms, selection of a modern operating system or platform that provides defense-in-depth properties, including ASLR which is a security technique involved in protecting against battery overflow, memory not executable, segregation process, and sandbox attacks. It is important to consider safe standard coding practices of industries, such as OWASP, SAFEcode, among others, to minimize the risk of attacks to applications.

Security in the hardware platform, ensures that hardware platform provides the essential security features. This involves some aspects, such as booting ROM, cryptography, proper circuit design, device access interfaces, component packaging, and power management.

Authentication, auditability and forensic registration, devices that in a connected environment can not be compromised, or be used as platforms entry points to launch attacks. It is necessary to validate objects that communicate with each other and with the platforms, as well as to consider distribution software such as Kali Linux to perform penetration audits to discover vulnerabilities.

Management and monitoring, ensuring that smart objects can be managed and monitored safely. Therefore, network monitoring systems must be implemented for connectivity of objects to allow us detect any change, or unauthorized access to the information, or to certain parameters of devices. For example, on the one hand, we can mention the proprietary tool PRTG Network Monitor with features such as compressive network monitoring, flexible alert systems, high availability cluster for uninterrupted network monitoring, distributed monitoring with remote probes, publication of data, and maps, on the other hand, we can opt for open software like Nagios.

Sustainability and the ability to update, features that facilitate the ability to safely update devices when vulnerabilities are discovered after release.

Each of these steps of the general scheme must be a continuous movement cycle, that allows us to have feedback based on records that are got in tests during development or in a real operating environment, or also from failures produced by attackers causing great losses, they should be solved immediately though.

3 Discussion of results

Most of smart objects, when talking about security, were not designed to be part of an interconnected environment, hence in some cases, some of them have been compromised, according to Karpesky Lab report [18], in 2017 there were more than 7,000 samples of malware targeting intelligent devices, and the most attacked were DVRs and IP cameras, where the majority of them were in China.

In academic environments where intelligent devices are developed [9], [15]–[17], where everyday objects are integrated sensors and actuators that through software we can interact with other devices or people using the internet, there is no security validation process that these devices must provide both at the logical level referenced according to the protocol stack of the TCP / IP architecture, and at the physical level.

These figures show us an overview of security in smart devices, so they should generate awareness when dealing with devices or objects connected to the Internet, so it is important to increase awareness of the security that must be taken in this regard, whether in academic or industrial environments.

4 Conclusions

Security is a primary issue for people, companies, or industries that use smart objects, not only because there could be financial operations in the middle that could lead to serious consequences in case of data leaks, but there also could be unauthorized access to vital systems that could lead to the loss of human lives or cause a mass disruption of society, that is, where there are smart objects on which people depend on, and they were vulnerable to attacks, such as medical devices, on the other hand, smart vehicles that could be intruded causing the driver to lose control and have an accident, as well as land, air or maritime traffic control systems where an attack to their systems could result in chaos of greater magnitude. With this regard, the aforementioned aspects have to be considered from a basic level of security awareness.

This research clearly identifies that developers of intelligent devices in academic and industrial environments would not consider safety a priority during design and development. When security is not taken into account in the production process of these devices, there is a serious risk that these objects may be susceptible and vulnerable to cyber attacks, since they were not designed to be in an Internet-connected environment.

5 References

[1.] Real Academia Española, "DLE:Diccionario de la lengua española - Edición del Tricentenario," 2017. [Online]. Available: http://dle.rae.es/?id=B3yTydM. [Accessed: 20-May-2018].

[2.] [Universidad Rey Juan Carlos, (8) Charla sobre Internet de las Cosas en la URJC por Carriots (06/11/2013) - YouTube. 2013.

[3.] B. Cedón, "El origen e historia del Internet de las Cosas (IoT)," 2017. [Online]. Available: http://www.bcendon.com/el-origen-del-iot/. [Accessed: 20-May-2018].

[4.] J. Pacheco and S. Hariri, "IoT Security Framework for Smart Cyber Infrastructures,"

in 2016 IEEE 1st International Workshops on Foundations and Applications of Self* Systems (FAS*W), 2016, pp. 242–247.

[5.] D. Kushner, "The real story of stuxnet," IEEE Spectr., vol. 50, no. 3, pp. 48–53, Mar. 2013.

[6.] C. Bracho, F. Cuzme, C. Pupiales, L. Suárez, D. Peluffo, and C. Moreira, "Auditoría de seguridad informática siguiendo la metodología OSSTMMv3 : caso de estudio," Maskana, vol. 8, pp. 307–319, 2017.

[7.] F. Cuzme, L. Suárez, C. Bracho, and C. Pupiales, "Diseño de políticas de seguridad de la información basado en el marco de referencia COBIT 5," in Innovando Tecnología, UTN., Msc. Daisy Ibaquingo, MSc. Cathy Guevara, MSc. Silvia Arciniega, MSc. Marco Pusdá, and MSc. Pedro Granda, Eds. Ibarra, 2017, pp. 129–137.

[8.] P. Casas, "El Triángulo de la Seguridad | Seguridad en Cómputo," 2015. [Online]. Available: http://blogs.acatlan.unam.mx/lasc/2015/11/19/el-triangulo-de-la-seguridad/. [Accessed: 20-May-2018].

[9.] V. Alvear-Puertas, P. Rosero-Montalvo, D. Peluffo-Ordóñez, and J. Pijal-Rojas, "Internet de las Cosas y Visión Artificial, Funcionamiento y Aplicaciones: Revisión de Literatura," Enfoque UTE, vol. 8, no. 1, p. 244, 2017.

[10.] F. Martínez, "Lo que el Internet de las Cosas representa para la seguridad - CIOAL The Standard IT," 2013. [Online]. Available: http://www.cioal.com/2013/10/24/lo-que-el-internet-de-las-cosas-representa-para-la-seguridad/. [Accessed: 20-May-2018].

[11.] Pitkit Zetes Smartech, "Perfil de la compañía: Pitkit Zetes Smartech." [Online]. Available: http://pitkitcards.com/spanish/profile.html. [Accessed: 20-May-2018].

[12.] C. Borghello, "Seguridad Informatica / Seguridad Lógica." [Online]. Available: https://www.segu-info.com.ar/logica/seguridadlogica.htm. [Accessed: 20-May-2018].

[13.] J. Ferrer and J. Fernández-sanguino, "Seguridad informática y software libre.," pp. 1–11.

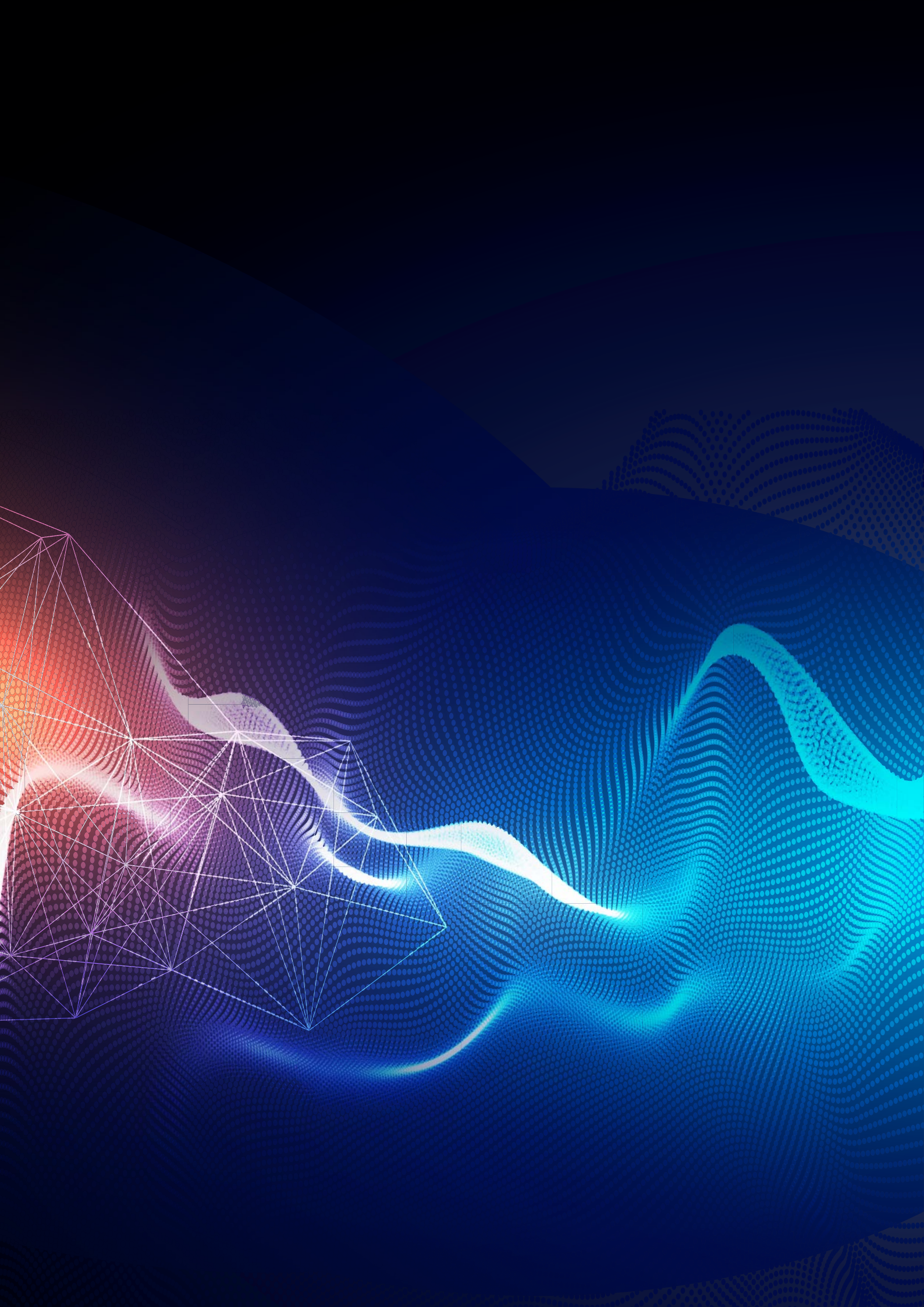
[14.] F. López Provencio, "Desarrollo dirigido por la seguridad," 2015.

[15.] H. Farinango, "Sistema electrónico con aplicación de visión artificial para iluminación regulable automática que brinde la cantidad de luz óptima en el punto focal de soldado en mesas de trabajo a escala de laboratorio," 2016.

[16.] J. Ruiz, "Sistema experto en el tratamiento de información de sensores para visualización de alertas," 2017.

[17.] T. Morocho and J. Rogelio, "Dispositivo de seguridad para alerta de manipulación, rastreo y localización de motos por medio de tecnología inalámbrica SMS Y GPRS," Jan. 2017.

[18.] Kaspersky Lab, "Karpersky: Boletín de Seguridad Estadísticas Generales de 2017," 2017.



Multicriteria Decision Analysis Applied to an Electrical Power System: Case Study

xavier.aguas@epn.edu.ec

Xavier Aguas, María Campoverde, Vanessa Benavides, Nataly Pozo, Marcelo Pozo
Departamento de Automatización y Control Electrónico Industrial
Escuela Politécnica Nacional
Quito, Ecuador

xavier.aguas@epn.edu.ec

ABSTRACT

Commonly, the interaction of power systems is to provide energy depending on the demand. The introduction of renewable energy to the electrical system brings a new challenge to the transmission system operator. This new challenge is related to the decision criteria due to the variability of the source that not necessarily match with the demand. Thus, the goal of this paper is to present a multicriteria decision analysis in order to set which power source could be used depending on the season. For this study, the decision deck software "diviz" is used. The results show that for dry and rainy season, hydropower is the best option.

Keywords: Decision making, multicriteria analysis, multicriteria, tradeoffs, electrical power system.

Introduction

In the last twenty years, the integration of renewable energy to the electrical system is now a reality. The total installed capacity considering marine, solar, wind and hydropower is closed to 2 GW [1]. The integration of these renewable energy affects to voltage and frequency stability [2]. This is because the demand does not match with the intermittent behavior of the source [3].

Therefore, the main challenge for transmission system operators is to adapt their decision not only to prices but also to availability of the source. For this decision some multicriteria decision making framework to rank renewable energy projects has been presented by several studies [4], [5]. For instance, Harambopoulos and Polatidis suggests a multi criteria method that includes: fuel saved, return on investment, environmental and risk index, and number of jobs created [6].

Different methods have been studied in order to rank renewable energy in the electrical system. Some of the multi criteria decision method are: PROMETHEE, ELECTRE, VIKOR, TOPSIS. The advantages and disadvantages of each method has been presented by [7]. Depending on the multicriteria decision method and weighting technique, the results can vary. The application of any method of multicriteria analysis assumes the need to determine which objectives of the decision maker intends to achieve. Other method that has not been deeply applied on renewable energy is the additive weighting method (AWM).

Thus, the present work evaluates an example of an electrical power system with different types of energy sources (hydroelectric, thermoelectric, renewables and non-conventional) considering the AWM. In the study, transmission lines, power compensators, and loads are also considered. The goal is to choose the best option of power source obtained by a hierarchical order. This procedure was performed manually and the results were validated with the software DIVIZ. The paper is structured as follow: the explanation of the multicriteria decision analysis is developed in Section 2. Then, the additive weighting method is explained and applied in section 3. Section 4 presents the results of the study developed. Finally, some conclusions are drawn.

1 Background on multicriteria decision making

The main strength of the multicriteria methods is their ability to rotate around questions characterized by contradictory assessments, allowing a comprehensive evaluation of the problem in question [8] . Multicriteria decision problems consist of a problem where there are at least two alternatives to choose, this choice is developed by the desire to comply several objectives that often conflict with each other. The objectives are variables that are associated with the evaluation and authorization of each alternative to fulfil a specific purpose. These variables can be called criteria, attributes or dimensions.

A decision model is a formal representation and simplification of the problem that has support of a multicriteria method to make decisions. These models help to describe and analyse the problem of interest. Through a multicriteria method, decisions are made to achieve the previously established objectives.

The basic elements for multicriteria decision are explained as follow:

- **Alternatives (a_n):** The concept of alternative corresponds to the particular case in which modelling is such that two distinct potential actions can in no way be conjointly put into operation.
- **Criteria (c_n):** A criterion is a tool constructed for evaluating and comparing alternatives according to a particular point of view. This evaluation must take into account, for each action, all the pertinent effects or attributes linked to the point of view considered.
- **Consequences:** It is the combination of the alternatives and criteria, forming a matrix with each element that represents the relationship between each of the alternatives and the criteria.
- **Problematic:** It presents a vision in the quality or result intended in a certain problem, can be identified in four types of problematic:
- **Choice problem** (α): Clarify the decision to choose a subset of the value space.
- **Classification problem** (β): Assign to each action a class.
- **Management problem** (γ): Sort actions.
- **Description problem :** Support the decision through a description of the actions and their consequences.

The procedure used to order the scale constants of each of the criteria will be the trade-off procedure. According to [9], the trade-off procedure has six steps:

1. Intra criterion evaluation: It consists in evaluating each alternative i for each criterion j, obtaining a value function for each alternative ($v_j(a_i)$). This function allows to construct an array of consequences that represents the problem to be solved.
2. Criteria ordering: If pairs of consequences are compared in order to sort the criteria according to the consequence they represent. This comparison is made considering that consequence 1 will have the maximum value for criterion i and the minimum value for the other criteria; However, consequence 2 will have the maximum value for criterion j

and the minimum value for the other criteria; Where i≠j.

3. Obtaining the relation between the scale constants: If comparisons are made based on the step of ordering criteria. The maximum value of the criterion of the preferred consequence is decreased and the values are maintained in the non-preferred consequence until an indifference relation is obtained.

4. Make all the necessary comparisons in order to achieve the values of weights.

5. Exploring the space of consequences: If you try to find more comparisons for the decision maker you will improve your assessment.

6. Consistency tests are performed on the results.

Several methods have been applied for multicriteria decision. In this paper, the additive method is the chosen for the present study. This helps to sort the options in a hierarchical structure, where numerical values are obtained that represent the priority of each alternative. The use of this method makes it possible to identify the criteria used for decision making, also provides a hierarchical structure, assigns weights to each criterion to establish its importance, thus synthesizing all information for better decision.

To carry out this method, it is necessary to find the value function ($v_j(a_i)$) for each criterion j. The general formulation of the problem is as follow:

$$v(a) = \sum_1^n k_i v_i(a) \qquad (1)$$

Where k_i represents a weight for criterion j.

$$\sum_{j=1}^n k_j \qquad (2)$$

For the determination of the weights for each criterion, the trade-off method is used. This method emphasizes the degree of importance of each criterion. The method establishes the degree of interaction between all variables. The systems are normalized, i.e. the scale is between 0 to 1, and the variables are ordered by importance, which are obtained by the additive method, i.e. the sum of all the criteria must be 1:

$$c_1 = 0.5\, c_7 \qquad (3)$$

$$c_3 = 0.9\, c_1 \qquad (4)$$

$$c_2 = 0.7\, c_3 \qquad (5)$$

$$c_4 = 0.9\, c_2 \qquad (6)$$

2 Case study

Fort the proposed methodology, a case study is proposed. In this case, the alternatives considered takes into account the type of power generation. These alternatives are:

- Hydroelectric power station.
- Thermal Power Plant.
- Non-Conventional Plants.
- Interconnection (losses, loads)

Additionally, the multicriteria for the decision making in an electrical power system is described as follow:

- *The generation of a structure at peak hour for a day of maximum power demand in the rainy season (c_1):* In a rainy period, hour of maximum demand is determined in as the time, respectively hour of the peak of demand. An analysis of the contributing of the energy sources is carried out, and as result of this analysis the percentage of contribution of each type of energy source is obtained.
- The structure of generation in a day of maximum demand, in rainy period (c_2): In a rainy period, the day of maximum demand is determined as the time in which the peak of demand exists. An analysis of the contributing energies is carried out and the result is the percentage of contribution of each type of energy source.
- The generation structure at peak hour for the day of maximum power demand of the dry season (c_3): In a dry period, the hour of maximum demand is determined as the time in which the peak of demand exists. An analysis of the contributing energy types is carried out and the percentage of contribution of each type of energy is obtained.
- The structure of generation throughout the day of maximum demand, dry period (c_4): In a dry period, the day of maximum demand is determined, an analysis of the contributing energies is carried out and the result is the percentage of contribution of each type of energy.
- Generation structure in the hour of minimum demand of the year (c_5):The percentage of the energy provided by different types of energy generation is shown, for the hour of minimum demand.
- Structure of generation throughout the day of minimum demand of the year (c_6): The percentage of energy supplied by different types of energy generation is shown, by day of minimum demand.
- Total net energy production (c_7): It is the energy provided by the different types of energy generation, in GWh, in one year.

Taking into consideration these criterions and the weight factor, the order of each criterion is organized in table 1. Additionally, the normalized matrix where the relation of the alternatives and the criterions assumed are in table 2. In this case, more importance is given to hydropower and thermal station instead of non-conventional power plants.

3 Case study

Fort the proposed methodology, a case study is proposed. In this case, the alternatives considered takes into account the type of power generation. These alternatives are:

- Hydroelectric power station.
- Thermal Power Plant.
- Non-Conventional Plants.
- Interconnection (losses, loads)

Additionally, the multicriteria for the decision making in an electrical power system is described as follow:

- The generation of a structure at peak hour for a day of maximum power demand in the rainy season (c_1): In a rainy period, hour of maximum demand is determined in as the time, respectively hour of the peak of demand. An analysis of the contributing of the energy sources is carried out, and as result of this analysis the percentage of contribution of each type of energy source is obtained.
- The structure of generation in a day of maximum demand, in rainy period (c_2): In a rainy period, the day of maximum demand is determined as the time in which the peak of demand exists. An analysis of the contributing energies is carried out and the result is the percentage of contribution of each type of energy source.
- The generation structure at peak hour for the day of maximum power demand of the dry season (c_3): In a dry period, the hour of maximum demand is determined as the time in which the peak of demand exists. An analysis of the contributing energy types is carried out and the percentage of contribution of each type of energy is obtained.
- The structure of generation throughout the day of maximum demand, dry period (c_4): In a dry period, the day of maximum demand is determined, an analysis of the contributing energies is carried out and the result is the percentage of contribution of each type of energy.
- Generation structure in the hour of minimum demand of the year (c_5):The percentage of the energy provided by different types of energy generation is shown, for the hour of minimum demand.
- Structure of generation throughout the day of minimum demand of the year (c_6): The percentage of energy supplied by different types of energy generation is shown, by day of minimum demand.
- Total net energy production (c_7): It is the energy provided by the different types of energy generation, in GWh, in one year.

Taking into consideration these criterions and the weight factor, the order of each criterion is organized in table 1. Additionally, the normalized matrix where the relation of the alternatives and the criterions assumed are in table 2. In this case, more importance is given to hydropower and thermal station instead of non-conventional power plants.

TABLE VI
WEIGHTS OF CRITERIA

Order	Criteria	Weights
1	C7	0.3847
2	C1	0.1923
3	C3	0.1731
4	C2	0.1212
5	C4	0.1091
6	C5	0.0109
7	C6	0.0087

Table II
STANDARIZATION MATRIX

Alternatives	C1	C2	C3	C4	C5	C6	C7
Hydroelectric Power Station.	0.5956	0.6688	0.5583	0.4672	0.4185	0.4899	0.5495
Thermoelectric power station.	0.3618	0.3182	0.4020	0.4880	0.5511	0.4333	0.3861
Non-Conventional Plants.	0.0383	0.0073	0.0187	0.0188	0.0190	0.0501	0.0224
Interconnection.	0.0043	0.0057	0.021	0.0258	0.0114	0.0267	0.0419

4 Results of the proposed method

To begin the analysis, a study of each of the criteria and how affect the proposed alternatives is developed using the software "diviz". The analysis is developed by means of the star graph method, which shows an objective point of view, as shown in the figures 1 -4.

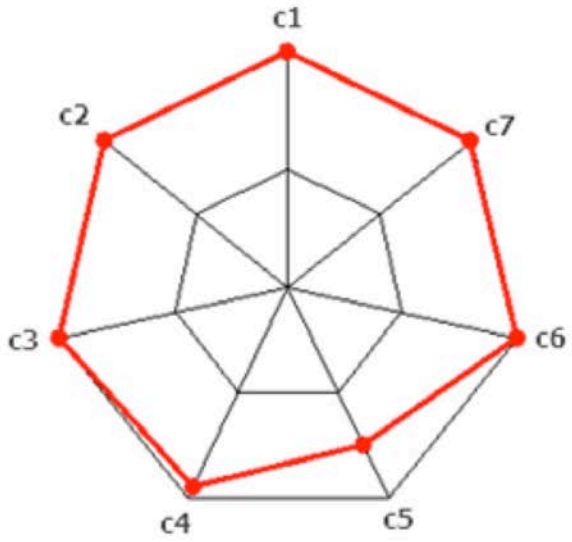


Figure 1. Polar representation of the Hydroelectric alternative.

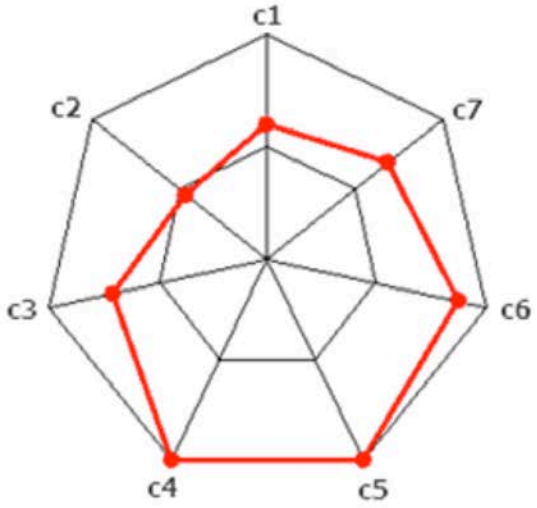


Figure 2. Polar representation of the Thermoelectric alternative.

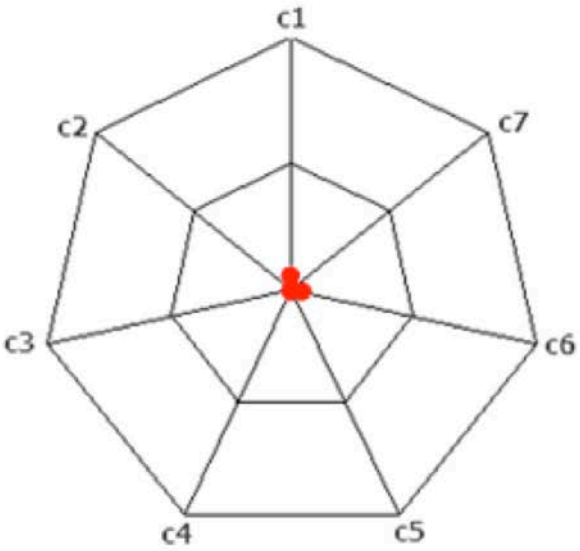


Figure 3. Polar representation of the Interconnection alternative.

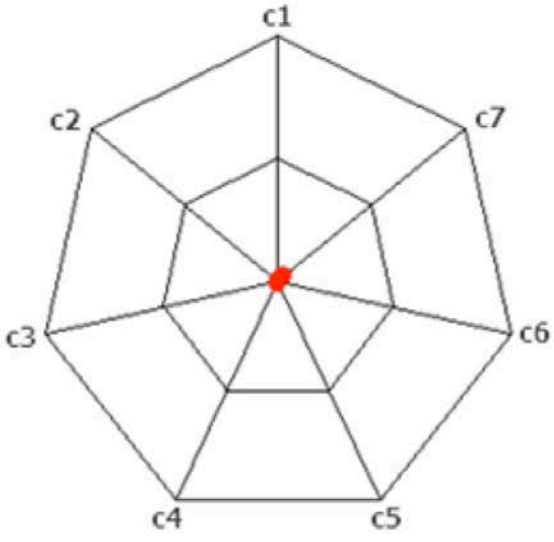


Figure 4. Polar representation of the Non-conventional Central alternative.

Each of the alternatives has been analysed according to the criteria of priority, the weights are estimated as it is shown Figure 5

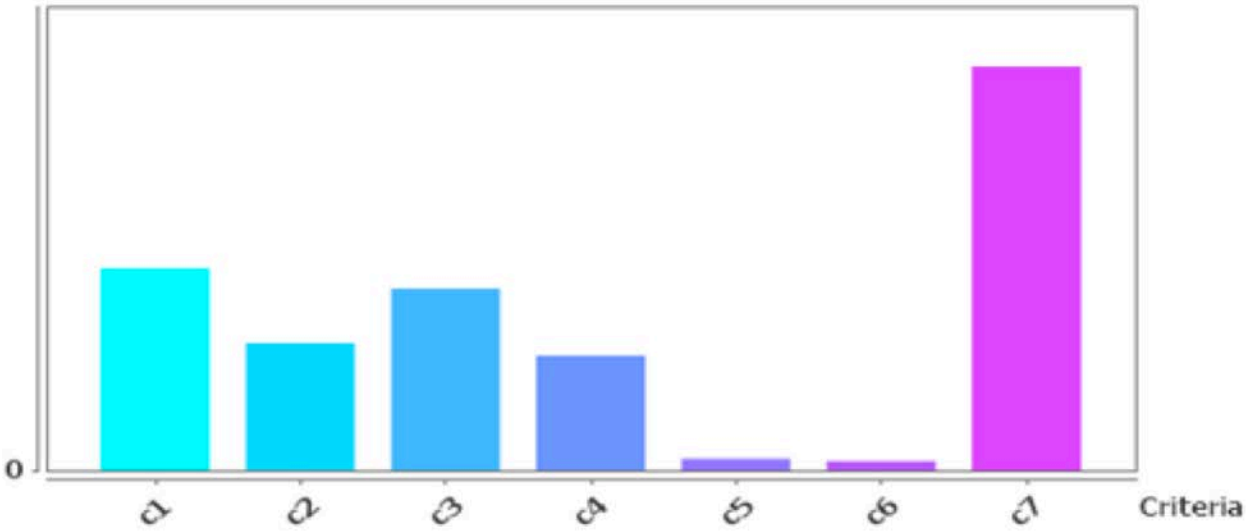


Figure 5. Bar Chart of Weights

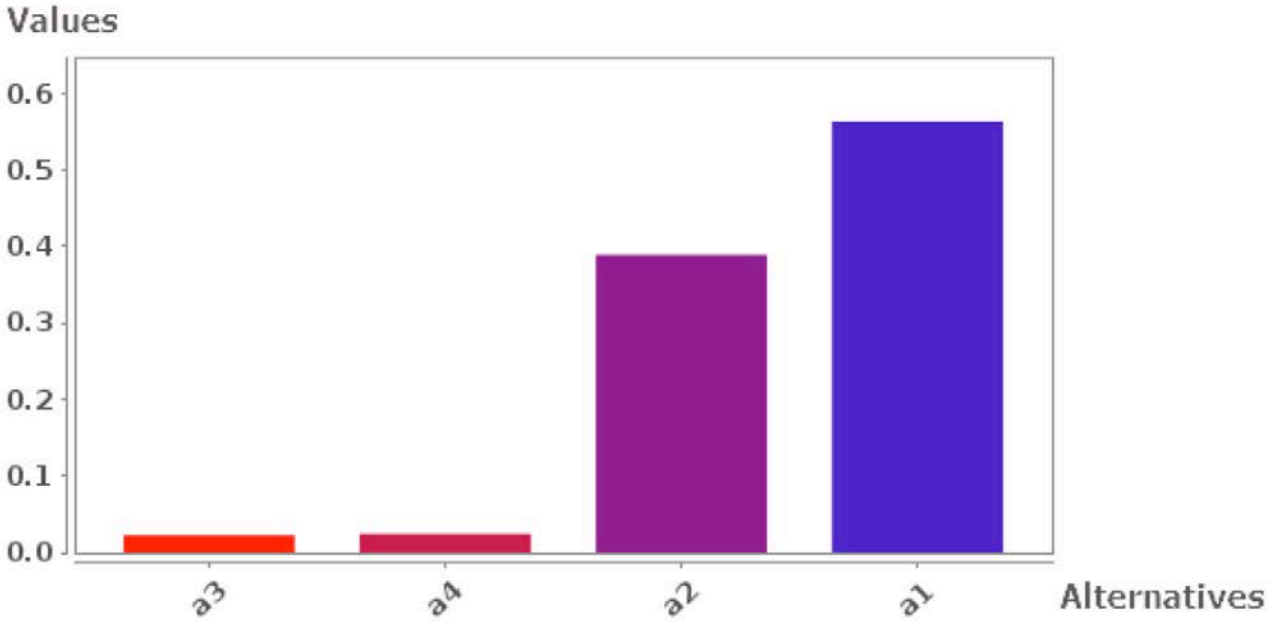


Figure 6. Sequential map showing what is the best alternative to be chosen.

According to the criteria and the weight, the best solution is alternative 1. This is that hydroelectric power station is the best used technology. This is because all the different criteria match with this solution. For instance, this technology offers the maximum power supply for the current demand for rainy season or dry season. However, the worst-case scenario is the non-conventional power plants due to the variability of the resource that affects in any time: dry or rainy season.

5 Conclusions

This paper has presented a multicriteria analysis for decision making method in order to find the best alternative. The study case is focused on a general grid that considers hydropower, thermal power plant, non-conventional generation and interconnection with other power systems. The different criteria were explained and studied. Then, the solution was modelled in "diviz" software.

The results show that the hydropower has the highest weight factors. This is because, it is considered that it has a larger contribution than the other alternatives. After using the trade-off method, the present method determined the hierarchical order of the alternatives. In this case, the first alternative is the hydropower and the last one is the interconnection together with the non-conventional.

6 References

[1.] "IRENA Resource." [Online]. Available: http://resourceirena.irena.org. [Accessed: 19-Feb-2015].

[2.] A. Cabrera-Tobar and O. Gomis-Bellmunt, "Dynamic study of a photovoltaic power plant interconnected with the grid," in IEEE PES Innovative Smart Grid Technologies Conference Europe, 2017.

[3.] T. H. Al-Theanat and M. A. Lpizra, "The Effects of Intermittent Solar Radiation in Off-grid Solar Power System A Case Study of Two Cities; Irbid and Abu Dhabi 'Worst Month' Method," Int. J. Eng. Innov. Res., vol. 4, no. 4, pp. 2277–5668.

[4.] B. Ozorhon, A. Batmaz, and S. Caglayan, "Generating a framework to facilitate decision making in renewable energy investments," Renew. Sustain. Energy Rev., vol. 95, pp. 217–226, Nov. 2018.

[5.] N. H. Afgan and M. G. Carvalho, "Multi-criteria assessment of new and renewable energy power plants," Energy, vol. 27, no. 8, pp. 739–755, Aug. 2002.

[6.] D. A. Haralambopoulos and H. Polatidis, "Renewable energy projects: structuring a multi-criteria group decision-making framework," Renew. Energy, vol. 28, no. 6, pp. 961–973, May 2003.

[7.] H.-C. Lee and C.-T. Chang, "Comparative analysis of MCDM methods for ranking renewable energy sources in Taiwan," Renew. Sustain. Energy Rev., vol. 92, pp. 883–896, Sep. 2018.

[8.] L. Abdullah and C. W. R. Adawiyah, "Simple Additive Weighting Methods of Multi criteria Decision Making and Applications: A Decade Review." 2014.

[9.] A. T. de Almeida, J. A. de Almeida, A. P. C. S. Costa, and A. T. de Almeida-Filho, "A new method for elicitation of criteria weights in additive models: Flexible and interactive tradeoff," Eur. J. Oper. Res., vol. 250, no. 1, pp. 179–191, Apr. 2016.


UTN
FICA