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Strengthening of the Ecuciencia Platform through Data Analysis and Visualization at the Technical University of Cotopaxi

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This applied research work focused on strengthening the Ecuciencia platform at the Technical University of Cotopaxi through the implementation of data analysis and visualization using Power BI and PostgreSQL. A quantitative approach with a descriptive design was employed to conduct an extraction, transformation, and loading (ETL) process that ensured data quality and consistency. The objective was to develop intuitive and meaningful key performance indicators (KPIs) to evaluate the scientific production of faculty, aiding informed decision-making. The dashboard validation indicated high satisfaction regarding its usability and interactivity, highlighting its relevance for the university community. The findings demonstrate the importance of visualization technologies in research, promoting a dynamic and collaborative environment. This model can be replicated in other institutions to foster a data-driven culture centered on innovation and scientific advancement.
Keywords: Data visualization, Power BI, analysis, scientific production, decision making.

1. Introduction

In today's digital age, the massive availability of data in all fields of knowledge represents a very big challenge for decision-makers, both strategic and operational (Tagarelli, Salinas, Caymes, & Blanchini, 2020). Data analysis and visualization are powerful tools to assist information-based decision-making within any type of economic sector, whether

commercial, industrial and/or services, including higher education. The Ecuciencia platform, developed by the Technical University of Cotopaxi (UTC) is a virtual space for collaborative research with the aim of uniting researchers according to their areas of scientific interest (Ecuciencia, 2024).

Ecuciencia has different functionalities programmed in Python through the Django framework aimed at collecting data on conferences, publications, presentations and other scientific production carried out by UTC research professors. However, despite its stable operation, this platform faces significant challenges in terms of the analysis of data stored in PostgreSQL and visualization of information in real time, which limits its effectiveness and scope.

That is why, in this work, the need to strengthen the Ecuciencia platform is addressed through the implementation of visualizations generated through advanced data analysis techniques in order to enhance the capacity of users to monitor, interpret and use information efficiently. Microsoft Power BI is used to generate interactive visualizations due to its intuitive graphical interface that is accessible from any device.

The objective of the study is to implement intuitive and meaningful visualizations that optimize the management of data stored in Ecuciencia, for which it begins by identifying the structure of the platform's database, then a process of extraction, transformation and loading (ETL) is applied with Power BI and ends by developing interactive visualizations that support the compression and use of the data. This type of initiative is relevant considering that in the last two decades, data visualization has become a fundamental tool for the exploration and communication of complex messages in disciplines such as statistics, business intelligence, science, journalism, among others (Cairo, 2018).

The relevance of this article lies in its ability to transform the way in which the data stored in Ecuciencia is managed and used. The proposal considers that it is necessary to go beyond simply collecting and hosting data in PostgreSQL, but that it is more pertinent to promote an eternal dynamic and informative academic within the Technical University of Cotopaxi. With the strengthening of Ecuciencia, it is expected to set a precedent for other higher education institutions (HEIs) that have the expectation of integrating technology and data analysis in their research processes.

(Quisaguano, Esquivel, Silva, & Lasluisa, 2024) establish that in the current business landscape, the ability to make informed and strategic decisions is crucial for the success and survival of organizations worldwide, which is why it is appropriate to strengthen Ecuciencia by incorporating advanced data analysis and visualization capabilities that contribute to informed decision-making. Despite the existence of large volumes of data, the inability to convert it into clear and accessible information and knowledge limits its usefulness and impact on the UTC research environment.

The study consists of an applied research that seeks to strengthen Ecuciencia through the analysis and visualization of data with a descriptive approach that collects, processes and presents information through real-time indicators of the data managed in PostgreSQL. The deductive method considers that the implementation of visualizations with Power BI generates improvements in information management, which is validated through a structured

survey aimed at experts. The technical methodology covers six stages that include a thorough analysis of the database, ETL processes, development of indicators in an interactive dashboard, validation tests and implementation of the proposal.

2. Bibliographic review

Currently, it is evident that both the academic and scientific community and the business community link Business Intelligence and Competitive Intelligence approaches to organizational activities and the development of their strategy, seeking to lay the foundations for the construction of intelligent, agile, flexible organizations with advanced capabilities for the definition, collection, analysis, exploitation and dissemination of information, regardless of the sector or market in which they are developed (Ricardo, Ramón, Igone, Hamurabi, & Karina, 2020). Data analysis is a process that involves the collection, transformation and modeling of data in order to obtain useful information that helps decision-making, continuous improvement and optimization of resources, this process is essential to validate hypotheses, trends and communicate the results in a clear and transparent way to contribute to the advancement of scientific knowledge.

2.1. Data Analysis

Data analysis is defined as the process of inspecting, cleaning, and modeling data with the goal of uncovering useful information, reaching conclusions, and supporting decision-making; This field has become increasingly relevant due to the large volume of data generated in various technological and scientific contexts, on the other hand, data literacy is essential for researchers, students, and professionals to handle and analyze this information effectively, which includes the use of advanced tools and techniques for data visualization and cleaning (Nassi-Caló, 2022).

Data analysis involves several key stages (Figure 1) and is extremely important in many areas, such as education, science, health, business, and public policy, helping to turn data into valuable knowledge. The objective is to generate useful information to support decision-making.

Figure 1 – Key stages of data analysis (Medina et al., 2018). In original language English

2.2. Data Visualization

Nowadays we talk about visualization, as a result of the fact that there is a certain tendency to show huge sets of data, elaborated in a graphic, close and didactic way for interpreters to understand (Sancho, 2019). These visualizations are important because they allow data and analysis results to be represented graphically, which facilitates their understanding, interpretation and analysis. This technique seeks to convert complex and abstract data into drawings, diagrams, maps and tables to contribute to users' understanding.

Visualizations must be characterized by transmitting data graphically, allowing them to be represented, interpreted and understood in a better way, their understanding can be provided through animated graphics, which tell stories and contribute to making the message closer and more attractive (Carpio, 2019). Data visualization has become critical to understanding it in a world full of raw data. Using a story to present the data can make it easier to understand by connecting the viewer to the information in an emotional way without neglecting the main goal of conveying the message clearly and concisely.

2.3. Types of Visualizations

There are several types of visualizations with different purposes depending on their purpose and data to be represented. Tabular visualization is the simplest and most straightforward option for representing data organized into rows and columns. On the other hand, to show numerical data in relation to another variable, line graphs (Figure 2) can be used, consisting of an X-axis (horizontal) and a Y-axis (vertical), this to show trends and changes over time or another independent variable (Vanrell, 2019).

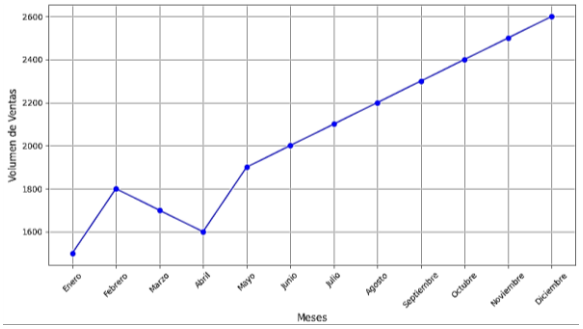

Figure 2 – Example of a line graph showing the months of the year on the horizontal axis and the dollar sales volume of a grocery store. In original language English

There are column visualizations that allow numerical data to be represented by rectangular bars of length proportional to the value to be represented, this type is useful for quickly comparing different categories or values. Figure 3 shows an example of this type of visualization (Galindo, Ruiz, & Benavides, 2019).

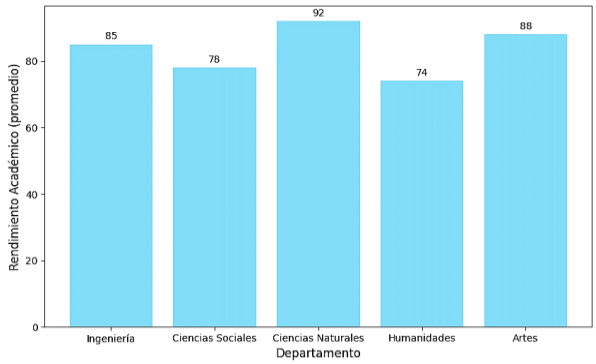

Figure 3 – Example of a bar or column graph where the averages by department of a university are compared. In original language English

2.4. Power BI

Power BI is a Microsoft software tool used for data analysis, allows users to gain valuable insights after processing data from various sources and displays a variety of results in a single visualization for better decision-making (Rios Morante, Echeverria Briones, Ruilova, Díaz Avelino, & Caizahuano Andrade, 2023). The benefits of Power BI include the ability to use it from anywhere, the ability for users to integrate their applications and collaborate with others as they see fit, the ability to track goals and get real-time reports (Díaz Vásquez, Acosta Espinoza, & Checa Cabrera, 2022).

An outstanding point of Power BI is its versatility to generate visualizations, interactive reports or even design dashboards (Saltos-Mero & Cruz-Felipe, 2024). In order to process large volumes of data and thus have an accurate decision-making, the features and benefits of Power BI are represented by data modeling, variety of graphs, the ability of users to integrate their applications and use them from anywhere.

2.5. PostgreSQL

PostgreSQL is an open-source relational database management system, highly valued for its stability, power, robustness, and ease of administration and implementation; it uses a client-server system with threads to correctly process database queries (Pilicita, Borja, & Gutiérrez, 2020). PostgreSQL works with the SQL (Structured Query Language) language to manage and scale information loads effectively, efficiently, and securely.

2.6. PgAdmin 4

PgAdmin 4 is the main open source management tool for Postgres, it is designed to meet the needs of its users, both beginners and experienced, providing a powerful graphical interface that simplifies the creation, maintenance and use of database objects, it consists of a web service developed in Python that allows access to all the functionalities of the database, consultation, manipulation and management of data (García & Rodríguez, 2022). PgAdmin 4, is cross-platform which means it can run on different operating systems, including Linux, Mac OS, and Windows.

PgAdmin4 is a web-based application with a server written in Python and front-end pages

with Bootstrap, using the Flask framework, every time the user sends a query using the pgAdmin interface, the web browser sends the query to the web server and then the server passes the query to the PostgreSQL database (Gong, Erwee, & Rautenbach, 2019).

2.7. Extraction, Transformation and Loading Process

ETL processes (Table 1) develop the activities required for the construction of a data warehouse (DW) consisting of a large structured data warehouse. Firstly, there is the process in charge of extracting data from different sources, such data represent the raw material of any information system; secondly, there is the transformation process, in which the data collected is purified according to the objectives of the organization, removing those that are irrelevant; thirdly, the cleaned and transformed data is loaded into the Data Warehouse (Ledezma-Ibarra, Osuna-Millan, Flores-Parra, & Rosales, 2023).

Table 1 – Description of the extraction, transformation and loading process (Ledezma-Ibarra, Osuna-Millan, Flores-Parra, & Rosales, 2023).

Component	Entrance	Process	Exit
Extraction	Data sources, transactional systems, spreadsheets, text files, etc.	Selection	Raw data (loaded into memory)
Transformation	Raw data (loaded into memory)	Cleanup, transformation, customization, calculations, and application of aggregation functions	Data formatted, structured, and summarized according to needs (still in memory)
Load	Data formatted, structured, and summarized according to needs (still in memory)	Insertion	Data formatted, structured, and summarized with persistence in the DW

2.8. Ecuciencia Platform

All the research carried out at the Technical University of Cotopaxi is documented through articles, books, papers and projects; that need to be stored and viewed by the university community, to solve this problem the Research Directorate approves the implementation of a scientific platform called Ecuciencia (ecuciencia.utc.edu.ec) in charge of compiling the scientific and technological production of all the disciplines that are studied in the different faculties existing in the institution. All the information stored in the database of the Ecuciencia platform needs to be visualized in tools that the user can easily understand, for this it is necessary to perform tasks such as designing intelligent search methods, especially those associated with internal information and the scientific production of the institution (Corrales & Rodriguez, 2020).

The foundations of the development of new technologies are largely driven by knowledge, thanks to repositories that contain a set of scientific documentation. Human beings have the ability to develop new data that strengthen knowledge management. In addition, these repositories will allow human beings to search for information in a faster and more efficient way, without the need for limitations for any individual within the scientific community (Falconí & Rodríguez, 2021).

3. Research methodology and design

This study consists of an applied research aimed at the practical strengthening of the Ecuciencia platform through data analysis and visualization. In this regard, Castro et al. (2023) establish that applied research focuses its attention on identifying needs, problems, or opportunities in the context in order to subsequently apply knowledge and respond to these requirements. The level of research is descriptive since detailed information is collected, processed and presented in visualizations that reflect the current state of the platform according to the data that is managed in PostgreSQL.

Taking into account that a descriptive study is one that belongs to quantitative research and that presents a single study variable called the variable of interest (Ochoa & Yunkor, 2021). The following research question is posed: How do users perceive information management in the Ecuciencia platform after the implementation of data analysis and visualization techniques?, the variable of interest being the user's perception of the improvement in information management and decision-making.

A quantitative approach is used since an analysis of numerical data is made to establish key performance indicators that support decision-making in the UTC Research Directorate. It should be noted that the quantitative approach is one that allows data to be examined numerically, especially in the field of statistics (Otero, 2018). The deductive method is considered because it is based on the premise that there will be improvements in information management when implementing visualizations in Ecuciencia, this is verified through the collection and analysis of data from the users of the platform through structured surveys.

In the technical part for analysis and visualization, a methodology structured in six stages is followed (Figure 6). First, an exhaustive analysis was carried out by reverse engineering the PostgreSQL database where Ecuciencia stores the data from the UTC researchers. The structure was reviewed and together with the administrators of the platform, the necessary indicators to support decision-making were identified. Next, an ETL process was executed in Power BI aimed at extracting the relevant data, transforming it to ensure its consistency and integrity prior to its loading within the analysis and visualization software used.

The development stage of measures calculated in Power BI and key performance indicators (KPIs) was followed according to the criteria of Ecuciencia users. Then, interactive and accessible dashboards were designed and implemented, made up of visualizations that facilitate the understanding of the available data. To verify the usefulness of the proposal, validation tests are carried out to provide feedback to the graphs and adjust the design if necessary, finally, the dashboard of the Ecuciencia platform is put into production.

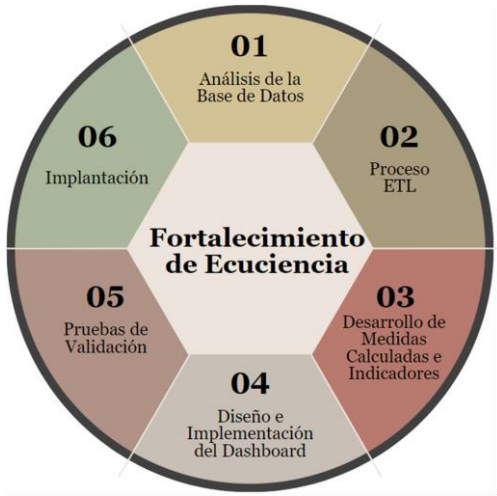

Figure 4 – Technical methodology for strengthening Ecuciencia. In original language English

3.1. Equipment Used

The equipment used to strengthen the Ecuciencia platform through data analysis and visualization at UTC is classified into hardware and software components as shown in table 2.

Table 2 – Equipment used to strengthen Ecuciencia through data analysis and visualization

Guy	Description	Detail
Hardware	Laptop	Dell brand, Core i7 / 7th Generation Processor, 16GB RAM, 1TB Magnetic Storage Disk.
Software	Operating system	Windows 10 / 64-bit
Software	Database Management System	PostgreSQL 12 / 64 bit
Software	Web Administration System	PgAdmin 4.24
Software	Data Analysis and Visualization Tool	Microsoft Power BI Desktop 2.112.603.0 / 64-bit

4. Results

4.1. Analysis of the Database

A reverse engineering process was carried out on the script of the Ecuciencia database in order to identify the existing structure and understand how the data are organized and what their relationships are. The result of this process was the entity-relationship diagram (Figure 7), which shows only those tables and relationships existing in the persistence layer that were considered to execute complex analyses and data visualizations in the present study.

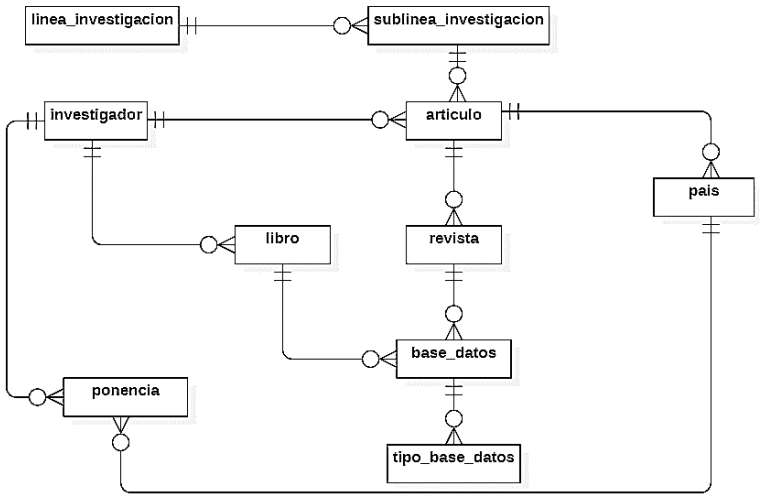

Figure 5 – Diagram of the entity relationship of the Ecuciencia platform. In original language English

4.2. ETL Process

The extraction, transformation, and loading process was performed using the PostgreSQL database and Power BI. Each of the steps described in Table 3 was followed.

Table 3 – Activities carried out for the ETL process

Process	Activities
Extraction	● Connection between PostgreSQL and Power BI. ● Selection of relevant tables and attributes for data analysis and visualization.
Transformation	● Data cleaning to avoid duplication, filling in null fields, standardizing accent and/or uppercase and lowercase formats. ● Creating calculated columns. ● Join data from different tables.
Load	● Upload the data to Power BI. ● Set up visualizations. ● Structure Dashboards. ● Share the Results.

4.3. Development of Calculated Measures and Indicators

The aim was to create metrics that provide significant findings that demonstrate knowledge derived from the data hosted on the Ecuciencia platform, these metrics compose key performance indicators aligned with the objectives of the UTC in relation to enhancing scientific production and research activity in teachers. Below are the KPIs established to support decision-making:

- Third-level, fourth-level, master's and doctorate degrees, the most recurrent in research professors.
- Publication of articles and papers by country.
- Total number of article publications per journal.
- Publication of articles by impact factor.

- Publication of books by publisher.
- Most recurrent line and subline in articles.
- Publication of articles by broad, specific and detailed field.
- Total books, articles and papers per career.
- Total books, articles and papers per faculty.

4.4. Dashboard Design and Implementation

The design and implementation of the dashboard was carried out using PowerBI Desktop and seeks to facilitate the visualization of key data that allows those responsible for the Research Directorate and authorities of the UTC to make decisions based on information, the findings are presented graphically through indicators that show trends and areas of improvement in scientific production. In addition, the institutional color palette was incorporated in each of the visualizations to represent the university identity in both the bar, linear or circular graphs as can be seen in Figure 6.

Figure 6 – Dashboard of the Ecuciencia platform. In original language English

4.5. Validation Tests

The validation was carried out through a questionnaire with a Likert scale aimed at collecting the criteria of 3 research professors who, after using the dashboard in Power BI, determined its usability, clarity, relevance and impact. The results obtained are presented in Table 4.

Table 4 – Result of the validation of the dashboard with experts

			Assessment		
No	Criterion	Question	Expert 1	Expert 2	Expert 3
1	Ease of Use	Understand how to use the different visualizations available	Totally I agree	I agree	Totally agree
2	Clarity of Information	Visualizations help identify relevant trends and patterns.	Totally I agree	Totally I agree	Totally I agree
3	Relevance of indicators	The indicators presented are relevant for the evaluation of scientific production	I agree	I agree	I agree
4	Interactivity	I can easily compare different faculties and careers through the dashboard.	Totally I agree	Totally I agree	Totally I agree
5	Institutional Identity	The design of the dashboard adequately reflects the institutional identity of the university.	I agree	Totally I agree	I agree
6	Overall Satisfaction	I consider this dashboard to be a valuable tool for our university.	Totally I agree	Totally I agree	Totally I agree

4.6. Implementation

After the testing process was satisfactory, a Power BI Desktop file was made available to users, through which they can interact with each of the scientific production indicators designed and implemented in an intuitive way. It should be noted that the version of Power BI used is only supported for computers with the Windows operating system.

5. Discussion

The strengthening of the Ecuciencia platform through data analysis and visualization at the Technical University of Cotopaxi shows the importance of adapting technological tools to the specific needs of the university community in relation to scientific production. The results obtained during the validation of the dashboard show that there is satisfaction among the experts who valued the ease of use, clarity of information and interactivity of the visualizations, advantages obtained thanks to the use of Microsoft Power BI desktop. With the implementation of understandable key performance indicators, it contributes to informed decision-making, which strengthens Ecuciencia through the possibility of visually evaluating scientific production and showing if it is aligned with the objectives of the Technical University of Cotopaxi.

The ETL process performed in PostgreSQL has allowed a smooth integration of data, ensuring its quality and integrity, fundamental characteristics for a coherent data analysis.

Importantly, visualizations improve the understanding of information and also promote a more dynamic research environment, where knowledge can be shared and used effectively. As the digital era advances, it is essential that educational institutions explore, develop and implement technologies that strengthen their analytical capacities, marking a path for other institutions to follow this model and obtain benefits derived from data analysis in their scientific research processes.

Finally, this study demonstrates the feasibility of implementing intuitive and meaningful visualizations that optimize the management of data stored in Ecuciencia through the use of Power BI. This can be replicated in other universities, thus contributing to the development of a data culture that favors innovation and collaborative scientific advancement. Although there is the limitation that by resorting to Microsoft technologies the dashboard developed works only on the Windows operating system.

6. Conclusions

The implementation of interactive visualizations with Power BI allows monitoring and analyzing the scientific production of the research professors of the Technical University of Cotopaxi, this strengthens the Ecuciencia platform by providing understandable information that supports decision-making that drives effective research and collaboration strategies.

The process of extraction, transformation and loading significantly improved the quality and consistency of data stored in Ecuciencia, which facilitated the process of analysis of scientific production whose results were mainly represented in linear, pie and vertical or horizontal bar graphs.

The use of the institutional color palette in each of the visualizations of the dashboard promotes a sense of belonging and cohesion within the university community, thus reinforcing the institutional identity and the commitment of the research processes at the UTC.

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