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Intelligent system for the optimization of eco-mobility operation processes aimed at public transportation in the state of Jalisco

Ismael Cardona[1], Edgar Gonzalo Cossio Franco[2]
[1] Centro de Tecnología Avanzada A.C., CIATEQ, Zapopan, México
[2] Instituto de Información Estadística y Geográfica de Jalisco
ismaelcardona66@yahoo.com.mx[1], edgar.cossio@iieg.gob.mx[2]

Abstract. The following work proposes a working model using artificial intelligence techniques to benefit employees working in public transport, specifically in the area of electric transport to batteries, with the help of data collection that this area generates daily, it is proposed to make a capture of these data and to start in a first instance, integrating predictive skills with the help of Machine Learning, for the prediction of autonomy for each bus in operation, to know the operating status of the batteries and to generate more efficient maintenance plans.
Keywords: Artificial Intelligence, Assets, Intelligent Integrations, Machine Learning.

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1 Introduction

This proposal seeks to generate and integrate in the first instance an integration based on artificial intelligence models using operational data from the first electric route in Mexico, collected through a digital tool for asset capture. This digital tool helps to organize labor information to carry out the operation of different work areas of a governmental public transportation institution (SITEUR) in the state of Jalisco, México. In the control and technology area, where the daily tasks of each of the employees become routine activities at different points in the metropolitan area of Guadalajara, the staff attends 3 transportation systems currently known as: SITREN System, MI MACRO CALZADA, MI MACRO PERIFERICO and LINEA ELÉCTRICA.

Integral urban electric train system (SITREN); LINE 1, 2, 3 and 4: this system consists of urban truck routes, in which the area in question monitors the video surveillance of the unit, radio frequency communication and control of the routes, in the event of a road accident, vandalism, crime or internal control, the area is requested to intervene to retrieve recording information to clarify the facts, the area goes to the site if it is urgent and the evidence is presented to the competent authorities requesting it.

Mi Macro Calzada and Mi Macro Peripheric systems: This is a bus rapid transit system or BRT (Bus Rapid Trans-port), in this area employees perform specific activities; control of the video surveillance system, maintenance and support for station breakdowns, lighting system, state Wi-Fi networks and supervision of contractors such as: private security for station users, cleaning service and collection of valuables.

Electric Route System: In this area the collaborators are in charge of charging the electric buses, monitoring and maintenance of electrical equipment such as bus chargers, monitoring the video surveillance system, support for radio communication breakdowns, road accidents, vandalism, crime or internal control of operators and passengers, control of route control which shows the route passage, in messages of lateral projection led to the upper front of the unit, and electrical system of the buses (headlights, internal bells, bodywork such as handrails, seat belts and ramps for the disabled).

2 The background of this study revolves around

In the 3 transportation systems mentioned above, which are currently in operation, field activities are performed, which are described above for each system, these tasks are recorded daily in the digital tool, generating a database with which you can be

sure of what is done in each shift, of each employee, also it is achieved to have an updated database and always available from anywhere with internet access and with the necessary permissions.

Thinking of being able to implement a system that helps to manage more efficiently specifically the Electric Route area, where the work for the management of the assets of this route has been different by the nature of innovation in terms of equipment and infrastructure to work with them, the work began rigorously analyzing the recorded assets that currently generates this system, in which we can see the following data: Charger identifier, Charge start time, Operation route, Unit identifier, Initial charge percentage, Charge percentage and mileage, currently we are adding a section to register the Kw/h consumed by each bus but at the moment the option to receive data is not enabled, we are only starting with a future integration for the digital tool. As shown in Fig. 1

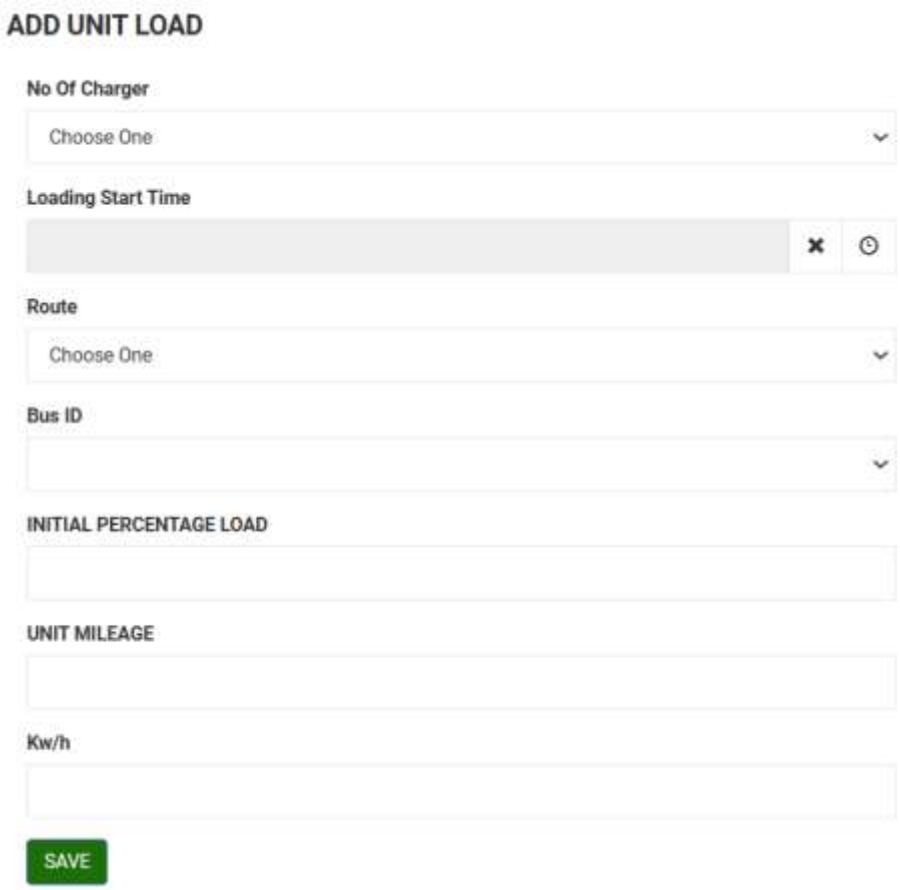

Fig. 1 Electrical unit load data logging startup screen.

The investigation of how to treat the data in this area that was relevant and significant began and found the work of (Rokde & Thosar, 2023) where he details how renewable energy sources (RES) are being developed moderately as new generation additions to the modern electrical system. These developments perturb the stability of voltage and frequency in the distribution power lines, for this the occurrence and perturbation data were analyzed by adding a spring device or electric spring which for the research studies the data of the variation of the load impedance generated by the RES to the electrical network by analyzing the performance of the electric spring through MATLAB simulations, The loads considered are linear. The results obtained from the simulation study are used to build a mathematical model using a simple linear regression technique.

Analyzing the above, this article was of relevance to form the beginning of a firm analysis oriented in data work, highlighting linear regression, since in the work of (Rokde & Thosar, 2023), it was possible to determine the relationship between the independent and dependent variables. Linear regression equations were constructed for P is, Q is and V is using the aforementioned independent variables, which allowed studying the behavior of energy storage (ES) under under and over voltage conditions. In addition, it was used to reduce computational complexity by generating dependent equations valid for different impedance values and load types. Linear regression was also used to perform correlation analysis based on the R^2

value between the independent and dependent variables under under and over voltage conditions. For the purpose of this work, the linear regression used in (Rokde & Thosar, 2023) was fundamental to model and understand the relationship between the variables involved in the study of energy storage behavior under different voltage conditions.

With the orientation of the previously detailed work, it is proposed to integrate in the first instance, simple regression techniques to treat data such as the KM traveled at the beginning of each bus load, the initial load percentage, and the time it takes to load from the current percentage to the end (100%), aided by the database generated by the digital tool, it is not proposed to use MATLAB as highlighted in (Rokde & Thosar, 2023), but rather to support the work with the help of machine learning tools such as Machine Learning.

Based on (Mahmud et al., 2023), he details how in his research, vehicle miles traveled (VMT) is essential information in various aspects of transportation engineering, and accurate estimation of VMT is crucial for practicing engineers. The use of linear regression models stands out, as they represent a widely used approach to estimating VMT, since they enable understanding of the relationships between VMT and other external factors. An important point to note is that, in these models, the prediction of the response variable has a non-zero probability of generating a negative value. For this reason, it is mentioned that the natural logarithm of the VMT is commonly used as the response variable to guarantee a positive result. However, log-linear regression (LLR) models provide a median estimate of the VMT rather than an average estimate. To address this limitation of LLR models, this study suggests the application of heteroscedastic LLR and data counting methods for VMT estimation. Since as suggested by (Rokde & Thosar, 2023) these methods perform better than LLR models in terms of data fitting and prediction accuracy.

2.1 Definition of problem

SITEUR (SISTEMA DE TREN ELECTRICO URBANO), is recognized for being a public organism of the state, dedicated to public transportation in the state of Jalisco, at the service of the citizens. The department of the multimodal transportation technologies department faces a problem in managing the information of the action logs that workers fill out when performing their daily tasks and carrying out the administrative procedures of this department, decreasing the efficiency in work performance due to factors of authorization of activities or the administrative branch, causing low productivity of the department and a rise in their economic reports that negatively impact the system, such as: rework tables, delay of reported activities and complaints of internal administrative inconsistency.

Computer applications are present unnoticed in an everyday environment, directly impacting the lifestyle of those who work in an area where cell phone access is not restricted during working hours as mentioned in (Rokde & Thosar, 2023). This is the case of the control and technology department, which has a dead time impact on work since, as mentioned in the following research, it shows that interruptions or distractions in work centers can occur due to the use of cell phones, a notable example of this would be the use of cell phones such deficiencies would be: phone calls, text messages, non-productive conversations, (social networks) causing the loss of more than a quarter of the working time (Mahmud et al., 2023).

The rise of digital applications has forced organizers, managers, and managers to incorporate digital environments that facilitate their interconnection with globalized environments, digital transformation is nothing more than seeking the adaptation of companies to the technological changes of the environment and lead them towards competitiveness (Silva Ortega et al., 2019).

Hence the need to involve all the human talent around technologies, towards new processes and labor management models as a way to grow the organization of the environment where the area of transport SITEUR is dedicated to is circumscribed.

Focused on looking for possible gaps that generate low productivity in addition to the processes identified above, this research focuses on the personnel, analyzing the employees in the technology area, which is made up of 32 employees, 21.9% of whom are over 45 years old, 31.3% are under 30 years old and only 46.9% are under 26 years old, respectively, as shown in Figure 2.

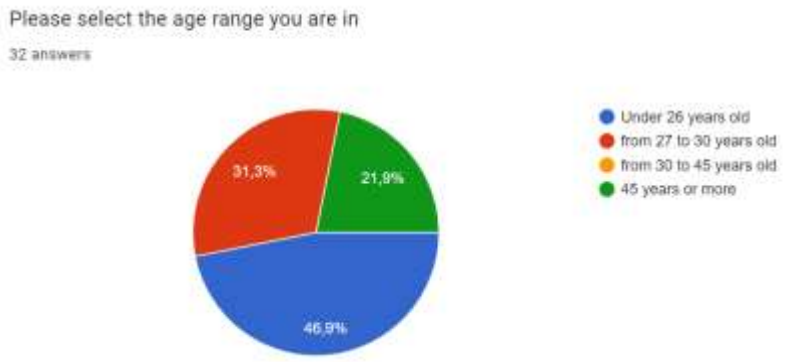

Fig 2. Age Ranges.

Being specific with the electric route area, 100% (5 collaborators) of the same age range stand out, denoting a young workforce. As shown in Figure 3.

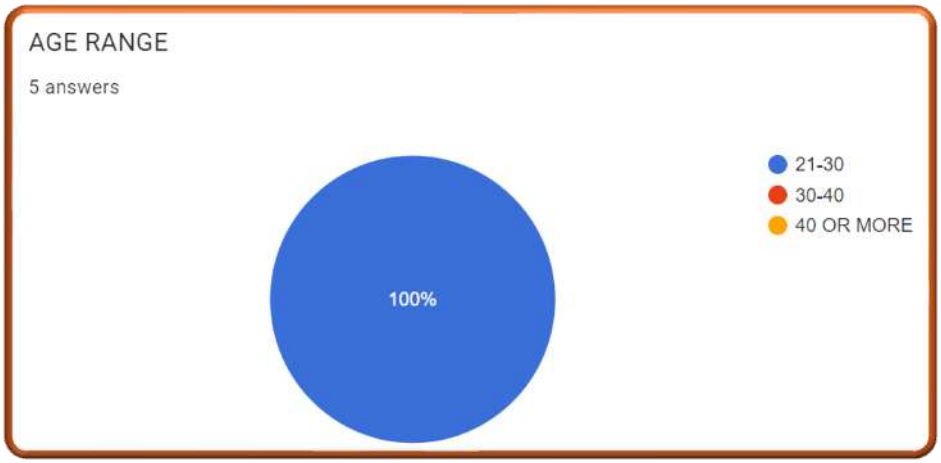

Fig 3. Age ranges electrical route area.

As explained in (Anghel & Lacuesta, 2020), it is documented that, as people age, certain skills related to the ability to perform physical work, reading and numerical comprehension or the use of new technologies deteriorate. For this reason, it is planned to take advantage of the experience acquired by the personnel of the area in their work career to reform a better planning, planning, and reaction against time, to give shape to the structure of the digital tool that is planned to be integrated.

	Low education		Secondary education		High education		All		
Skills	Spain	All (Averange)	Spain	All (Averange)	Spain	All (Averange)	Averange	Min.	Max.
Planning	1.84	1.69	2.01	1.90	2.25	2.17	1.98	0.13	3.88
Reading	1.32	1.35	1.81	1.82	2.46	2.44	1.99	-1.16	6.19
Writing	1.51	1.49	1.99	1.86	2.34	2.29	2.00	-0.08	6.51
ICT	1.57	1.45	2.01	1.79	2.19	2.24	2.00	-0.34	6.29
Mathematics	1.71	1.59	2.10	1.88	2.27	2.22	1.98	-0.10	6.73
Physical Effort	3.87	3.96	3.19	3.44	2.43	2.25	3.12	1.00	5.00

Fig 4. Age Range. [4].

Task and associated skills	
Skills	**Task**
Planning	Planning one's own activities and the activities of the others, organizing time.
Reading	Read documents (addresses, instructions, letters, reports, e-mails, articles, books, manuals, invoices, diagrams, maps).
Writing	Writing documents (letters, reports, e-mails, articles, forms).
ICT	Use e-mail, internet, spreadsheets, dosuments, processors, programming languajes, perform online transactions, participate in conversations (transfers, chats).
Numerical	Calculating prices, costs or budgets; using caculators; preparing graphs or tables; (algebra or formulas; advanced mathematics (calculus, trigonometry, regression).
Physycal effort	Frequency of physical work for long periods

Fig 5. Age Range (Anghel & Lacuesta, 2020).

On the other hand, the aim is not to invade the mental or family health integrity of the worker beyond the working day, which is 8 hours. This is indicated by the study carried out in (Pérez Rodríguez, Palací Descals & Topa Cantisano, 2017), which details that there is a significant relationship between work shifts and the perception of conflict in which the work/family conciliation culture does not seem to have a significant moderating effect. With this in mind, it is proposed that the tool should be, without sounding exhausting, useful within the shift, avoiding its use outside the working day at all.

3 Methodology

One of the most notorious efforts that are presented for the realization of this work is the channeling and obtaining of data, which with the help of the digital tool can be collected in a clear and effective way to be able to make use of them for any necessary action.

In this context, to avoid the waste of dead time that the idea of managing information through the use of cell phones in favor of labor productivity focused on the problem of control area and technologies, in order to obtain benefits in terms of performance and labor utilization, and once this has been obtained, to demonstrate whether it is also possible to obtain financial benefits, in addition to other factors as a consequence, such as:

- Increased productivity utilization per work shift (being 8hrs).
- Time reduction in the registration process of administrative procedures.
- Possible economic savings based on overtime and consumable resources such as paper, toner and electricity.
- Information is always organized, updated and available 24 hours a day.

For the innovation proposal related to the area of electric routing specifically, which seeks to estimate how many additional kilometers a unit could travel before needing a new 100% charge, this with the help of the data, kilometers of public transport units, as input and core, in order to guide the artificial intelligence model based on linear regression models and regression based on decision trees. which is proposed here below.

3.1 Data collection

In this section we capture the data generated daily in the electric route area, specifically, we will focus on the dates, unit identifier and the kilometers traveled in each load accumulated by each unit.

Once the data have been collected, they will be grouped by type, and then sorted consecutively from the oldest to the most recent data, thus concluding the first phase.

3.2 Data processing

The idea of implementing a Machine Learning model is proposed, to be integrated to the digital tool, considering the use of linear regression models or regression models based on decision trees.

Especially focused on the Neural Networks model, with characteristics of being a single layer trained model, this analyzed previously to the work done in (Shabaniet et al., 2023), which details how it addresses the temperature prediction of lithium-ion batteries in a metal foam thermal management system using artificial neural network models. The study compares the performance of different neural network models, including backpropagation neural network (BP-NN), radial basis function neural network (RBF-NN) and Elman neural networks (Elman-NN). Since The results show that the Elman-NN model in this

single-layer case has better adaptability and generalization ability for temperature prediction in the metal foam thermal management system.

Based on the above, although the paper presents advances in lithium-ion battery temperature prediction using neural network models, it also highlights the need for further research and improvements in this field to address existing challenges and limitations. Therefore, to create a trained model, certain factors must be taken into account for the proposal in question, which are detailed below.

To predict the autonomy of the units based on factors such as initial charge percentage, kilometers traveled, and kilowatt-hours consumed. These regression models can help the electric area system estimate how many additional kilometers a unit could run before needing a new 100% charge, and thus optimize operating times both in terms of bus use and operator schedules.

As mentioned in (Manzolli et al., 2022), for electric bus fleet management, research has been developed in areas such as electric bus system planning, charger location planning, and charging scheduling. These topics are identified as the main lines of research in electric bus fleet operation. Predicting this data will help SITEUR to know based on mileage how much a truck can perform on either of the two routes on which this line operates, avoiding incomplete turns, and avoiding service disruption. Meanwhile, the predicted data based on the KWh would serve as a tabulator to know the cost that generates the system load the bus and see if there are deficiencies in the economic performance generated by each electric bus and detect in time deficiencies or affectations that this can generate.

These models can also be used to estimate the autonomy based on different scenarios, which will allow us to make good decisions about the management of the units, to prevent them from arriving at the charging area with less than 20% charge. It is very common for buses to arrive in these conditions, being forbidden, which is very worrying since as mentioned in (Manzolli et al., 2022), the recommendation by battery manufacturers and professionals in the energy field is to avoid discharging the battery more than 20%, because deeper discharge levels can accelerate battery degradation and reduce its useful life. This is because operating the battery at higher discharge levels increases the cyclic and calendrical degradation rates, which can negatively affect the long-term capacity of the battery.

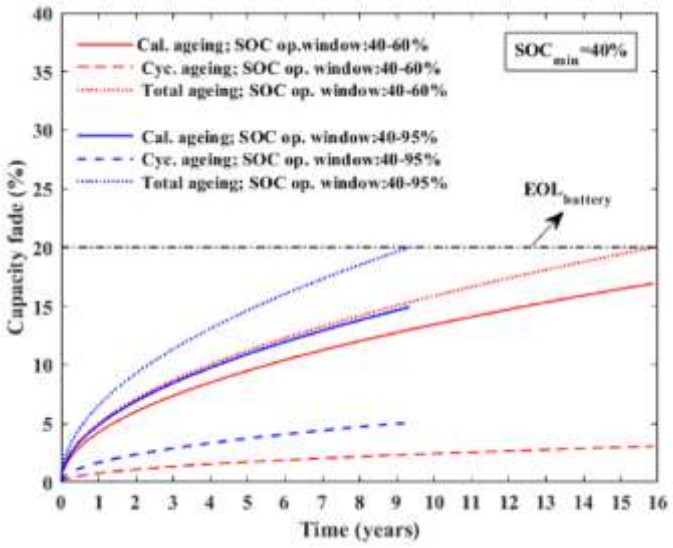

Fig 6. Discharge slope (Manzolli et al., 2022).

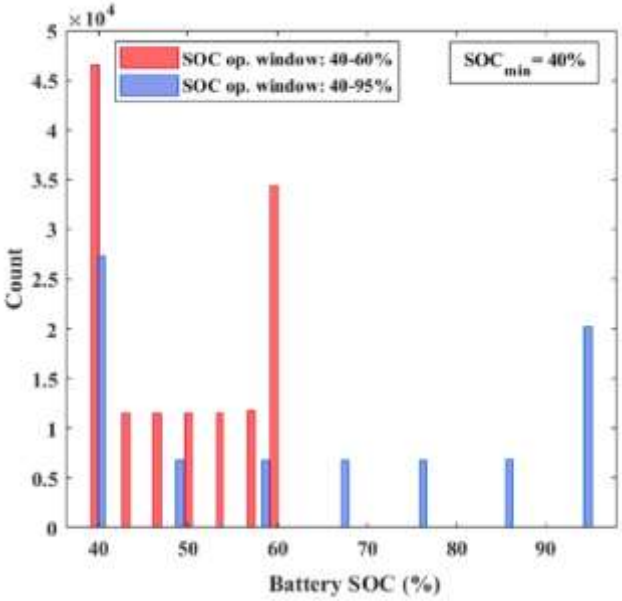

Fig 7. Average load start (Manzolli et al., 2022).

A data analysis model was defined thanks to the collection of data in real time, this is of vital importance since it would allow us to analyze in depth the optimization of processes and with the correct data processing methods, the early detection of problems.

With this data in mind, an analysis of the data that has been accumulated historically over a period of 3 years was started, only in the area of the electric route, giving a total of more than 30,000 records, which are divided into groups, as shown in the figure 8.

ID CHARGER	UNIT	DATE	START	END	% LEVEL START	% LEVEL END	DURATION	KM	Kw/h	START USER CHARGE	END USER CHARGE
1036767901	C98 - UE-037	14/7/2021	12:50	15:22	42%	100%	02:32	2,931	0	icardona	icardona
1036766501	C98 - UE-019	14/7/2021	12:47	14:00	40%	100%	01:13	2,818	0	icardona	icardona
1036766501	C98 - UE-026	14/7/2021	11:25	12:00	71%	100%	00:35	2,796	0	icardona	icardona

Fig 8. Database table short view.

The data had to take different order structures and arrangements to be used with statistical tools to find patterns of relationship between them. To give an example, the dispersion analysis, applied to the data sets; % LEVEL START and DURATION.

Using statistical tools such as Minitab, a session is created where a graph is generated between the data to see if there is a relationship of any kind. The following is one of several graphs with which the data analysis is interpreted.

↓	C1	C2-D
	% LEVEL START	DURATION
2	58.00%	00:52:00.000
3	57.00%	01:16:00.000
4	55.00%	01:05:00.000
5	55.00%	01:00:00.000
6	55.00%	00:59:00.000
7	54.00%	00:57:00.000
8	53.00%	00:58:00.000
9	52.00%	01:14:00.000
10	52.00%	01:02:00.000
11	51.00%	01:06:00.000
12	50.00%	01:11:00.000
13	50.00%	01:06:00.000
14	50.00%	01:06:00.000

Fig 9. Table with data in Minitab.

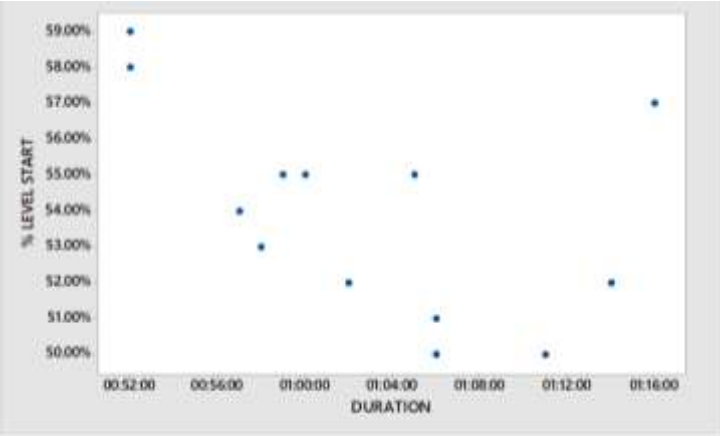

Fig. 10 Scatter plot showing that there is no relationship between data for attrition with irregular variation.

In the previous research where the work of (Manzolli et al., 2022) was referenced, the data obtained were analyzed to identify if we had the presence of bus load interruption incidents before they reach 100%, with the help of data filtering, the following information was obtained.

	C1-T	C2
	Colaborator	No. of incomplete loads
1	icardona	30
2	vcastro	35
3	isalcido	0
4	jmurguia	81
5	oruiz	18
6	jrodriguez	3
7	faguilera	1
8	eleon	1

Fig. 11 Table of data with records of incidents interrupted bus loads by contributor.

Considering these data in the Minitab tool, a statistical procedure was initiated with a focus on quality tools, using the Pareto diagram as a procedure, to prioritize problems that this exercise highlights, as well as to identify opportunities for improvement and to provide an effective control and follow-up process. The following figure will give us an overview of the data shown above.

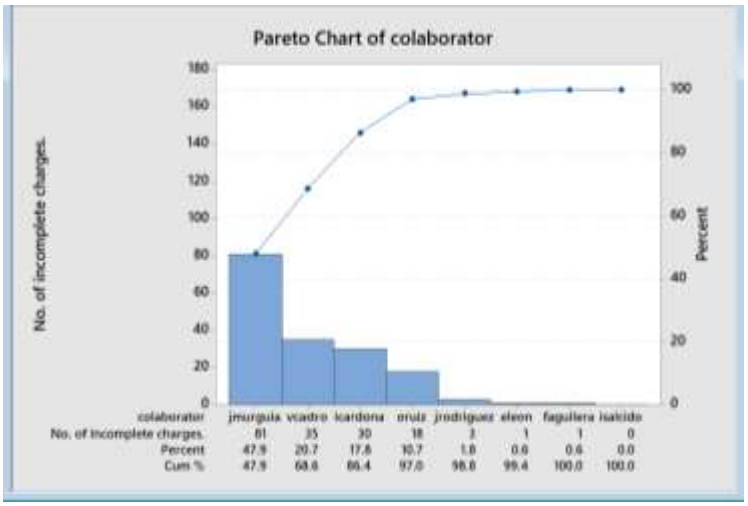

Fig. 12 Pareto chart for bus load interruption incidents.

In the graph, we can see how the bars are presented in descending order of importance, with the most important cause in this case being jmurguia, the collaborator with the most incidents of this type, and with the greatest relative magnitude after vcatro and last in hierarchy with icardona, this is of utmost importance to prevent these events from occurring and can be addressed before they cause a major problem.

Once the optimization proposal has been identified, as well as its feasibility, based on the literature repository, a series of stages are processed to create a series of stages which will be crucial to carry out to carry out the artificial intelligence proposal with the methods.

Once the optimization proposal has been identified, as well as its feasibility, based on the literature repository (Silva Ortega, Giler Valverde & González Soriano, 2019), a series of steps will be crucial to carry out to realize the artificial intelligence proposal with the methods.

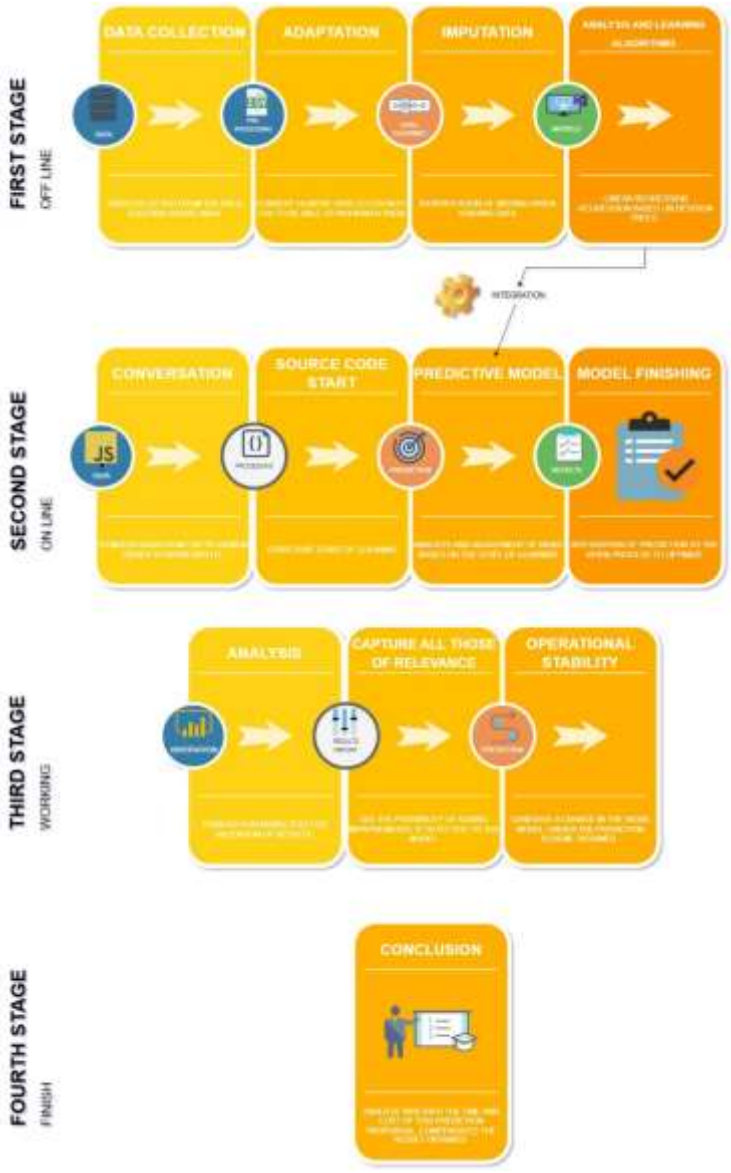

Fig. 13 Working Methodology.

Making use of Information and Communication Technologies (ICT'S) and digital tools for the development of the proposal such as:

1- PHP (Hypertext Preprocessor).
2- HTML (HyperText Markup Language).
3- CSS (Cascading Style Sheets).
4- Code editors (Visual Studio Code, Sublime Text, Atom).
5- Frameworks CSS (Bootstrap, Foundation y Bulma).
6- Design tools (Adobe XD, Figma, Sketch or even online tools such as Canva).
7- Version control (Git together with platforms such as GitHub or GitLab).
8- Testing and debugging (Chrome DevTools and Fire-fox tools).

The creation and implementation of a digital application for the management of assets and the excessive use of untimely labor time is denoted, the indicators of use, noticeable savings margins and feasibility of use within the work area will be denoted with data obtained prior to the implementation of the digital tool, based on results obtained after its application.

Using sampling tools, a survey was conducted among the employees of the technology department, in which they answered 5 questions to find out their point of view about the implementation of this digital tool in their work activities.
Questions were as follows:

1- What type of operating system do you use?
2- What cellular company do you use?
3- What rate plan do you use?
4- Would you be willing to use your own mobile networks, using your own phone, for work, to reduce the use of paper formats and speed up the work in your area? Considering that you will not spend more than 300 mb per month of your data.
5- Does your phone constantly have bugs? (Crashes or closes apps out of the blue).

The results obtained by the department's employees are shown graphically below.

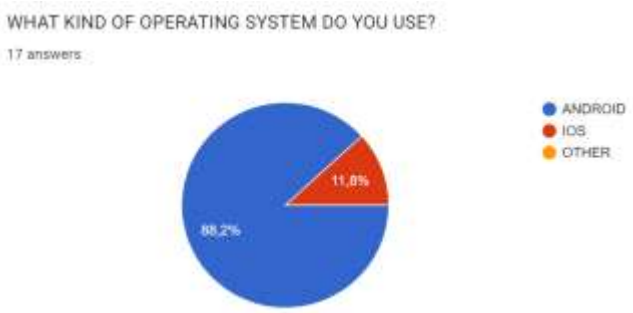

Fig 14. Smart Phone Survey.

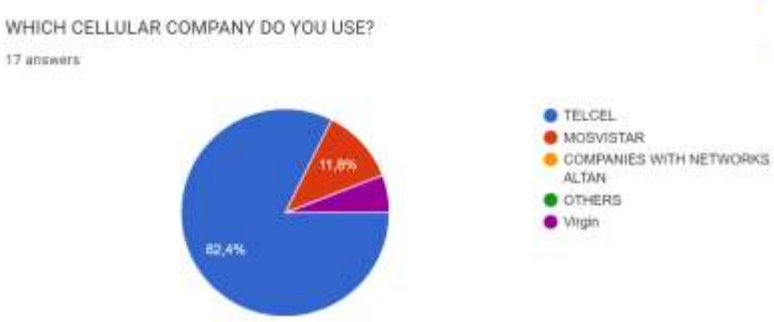

Fig 15. Smart Phone Survey.

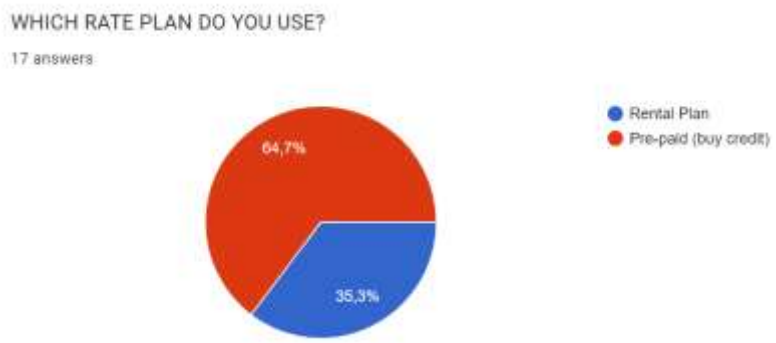

Fig 16. Smart Phone Survey.

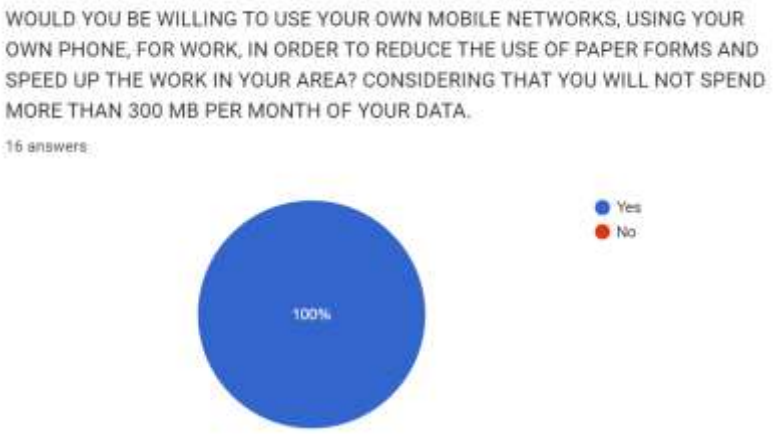

Fig 17. Smart Phone Survey.

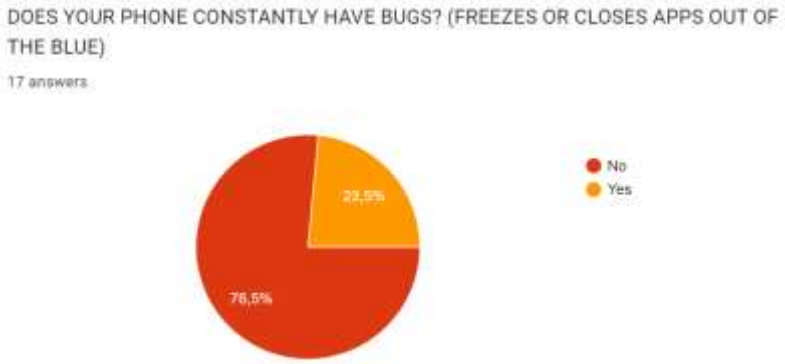

Fig 18. Smart Phone Survey.

In this aspect (Silva Ortega, Giler Valverde & González Soriano, 2019) defines the research method as a collective strategy that facilitates the development of the work, since it expands the investigative actions towards a conclusive end of methodological aspects.

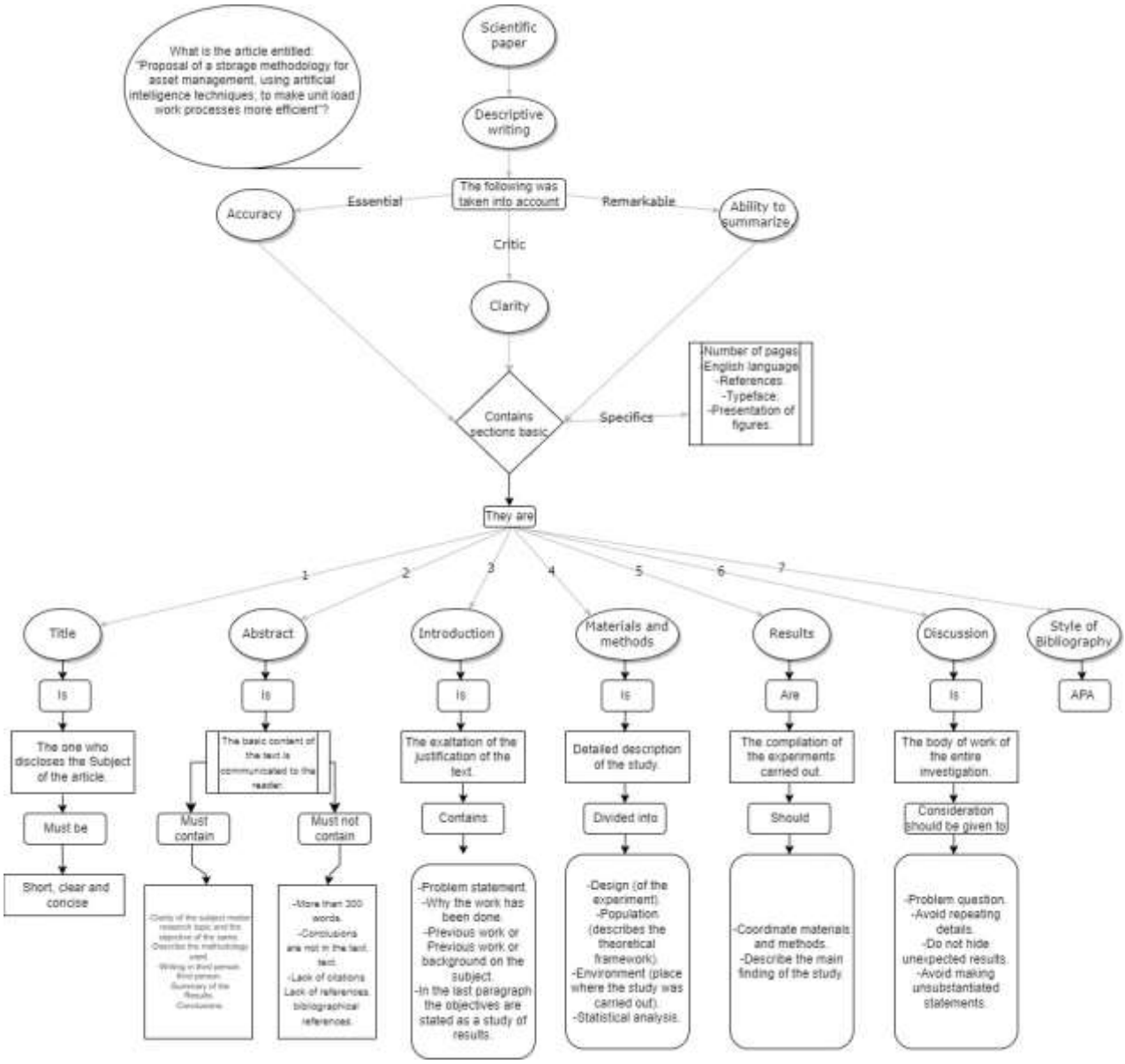

Fig. 19 Conceptual diagram of the body of the research.

Table 1. Comparative data table.

	Datum	Methodology	Results
Key elements	Text	Information search	Collection of background information on a specific problem without discriminating against any type of data.
	Numbers	Ordinance and grouping to enter them into statistical methods necessary for the research	Information to identify important factors to attack in the investigation.
	Dates and times	Classification by time series of data generation.	Data for demonstrative use of time series of actions presented.
	Ranks	Maximum and minimum limits for data sample collection, analysis indicators and defined scopes.	A definition of the scope of the research is obtained.
	Functions	Use of mathematical, statistical, programming and analysis tools.	Sequenced de-sampled indices of the data relationship used.
What is the point of research?	They make profound sense in this research for the following reasons: **Empirical Basis**: The data provide a solid empirical basis for the research being conducted. **Discovery and Verification**: Data allow us researchers to discover patterns, relationships, and trends in the information collected. **Objective Measurement**: Data provide an objective, quantitative measure of phenomena and variables. **Comparison and Contrast**: Data allow	They play an essential role in the research presented for several reasons: **Structure and Organization**: Methodologies provide us with a structure and organizational framework for the research process, as in this case the data collected. **Rigor and Reproducibility:** Methodologies promote scientific rigor by establishing standards and guidelines for data collection and analysis. **Coherence and Consistency**: Methodologies help maintain coherence and consistency in data collection and analysis	**Knowledge Generation:** One of the main goals of research is the generation of new knowledge, both for the researcher and the final reader. Answers to Research **Questions:** The data and methodologies help provide answers to the research questions posed at the beginning of the study, in this case it helps flesh out the theoretical

	researchers to compare and contrast different situations, groups, or conditions.	throughout a research project. **Variables Assessment**: Methodologies help researchers define and measure variables accurately, which is essential for understanding the phenomena being studied.	framework that was generated. **Pattern and Trend Discovery:** Data analysis can reveal patterns and trends in the information collected, in this case we have statistical graphs and in a future work will be the probability with the correctness of the information. **Validation and Corroboration:** Data support and validate the claims made in an investigation. The empirical evidence provided by the data increases the credibility and reliability of the results.

4 Conclusions

The article has multiple factors to be able to carry out the proposed objective, the digital tool for the capture of assets, as well as its outstanding functionalities that will integrate Machine Learning makes this work a multivariate perspective of what asset management is all about, integrating new technologies (AI) with rudimentary but accurate tools such as probability and statistical methods, to treat the data presented here in a comprehensive way with results that will lead to provide solutions not only to the system to which it is addressed but to any problem that needs it, knowing how to adapt its data and planning techniques for it.

With the results of this work, we will analyze the option of implementing it in other areas with similar problems that the control and technology department is facing so far, we are looking for an integral working model, friendly with processes of the same nature of asset capture and that is very useful at the time of integration immediately, without many adjustments, easy to use and friendly to employees, thus providing a methodology that adds value to the work environment of the SYSTEM highlighting other models of public transport and the use of the system in the same way.

The conceptual diagram that accompanies this article is a visual representation of the key dimensions and fundamental interrelationships that structure and guide the research. The diagram serves as an essential tool for understanding the underlying conceptual architecture of the article, highlighting in the first instance the main theoretical, methodological and empirical elements that make up the body of the article. Through this visual representation, it seeks to provide a panoramic view of the organization and internal logic of the study, thus facilitating a clear and coherent understanding of its structure and scope. The

purpose of this section is to guide the reader through the process of exploration and analysis of the various aspects of the phenomenon studied, thus contributing to a deeper and more holistic understanding of the findings and conclusions obtained.

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