Letters in High Energy Physics
ISSN: 2632-2714
Volume 2024

Descriptive Analysis and IoT Traceability for Measuring Vehicle and Load Conditions

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Received: 9/April/2024 Revised: 15/April/2024 Accepted: 15/May/2024

Abstract

This paper presents the results of a descriptive and traceability analysis of the Internet of Things (IoT), through the review of an experience or case analysis carried out in a transportation company in the city of Barranquilla. One of the most representative costs in the organizational world is usually the one corresponding to cargo transportation and vehicle maintenance; these represent up to 26% of the total costs of the final product in Latin American countries, due to the lack of control and identification of obstacles; hence the results outlined below, allow visualizing the importance of the insertion of technologies to reduce the high operating costs in the transportation sector, while facilitating the generation of reflections on the aspects to consider for the implementation of this type of initiatives.

Objective: The main objective of this research is to carry out a descriptive and traceability analysis of the IoT through the case study of a fruit transport company located in the city of Barranquilla (Colombia).

Results: The results make it easy to visualize the importance of elements such as sensors, applications and similar components in improving the quality of transport processes, and also favor aspects associated with maintenance and programming of highly important processes such as cargo movement.

Conclusions: The integration of advanced technologies in transport processes is essential to improve the quality and efficiency of logistics. The use of sensors and applications not only optimizes transport management, but also promotes greater safety and sustainability in operations. By addressing critical aspects such as maintenance and programming, a more fluid and organized cargo movement is favored, resulting in both economic and operational benefits for companies in the sector. Therefore, investment in technology and staff training is recommended to maximize the potential of these tools in the field of transport and logistics.

Keywords**:** internet of things; transport; business solutions; technologies; costs

CLASIFICACIÓN JEL: L81, L74, J12.

1. Introduction

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One of the most representative costs in the organizational world is usually the cost of freight transport and vehicle maintenance. These can represent up to 26% of the costs of the final product in Latin American countries due to the lack of control and identification of obstacles in the performance of logistics processes, a very high value compared to countries such as Canada and Germany, belonging to the Organization for Economic Cooperation and Development (OECD) whose figures are around 9% (EFE Agency, 2018).

According to various sources, high costs are often due to the lack of expertise, review and coordination for the full cycle of these processes (Speranza, 2018); Therefore, the importance of constant verification of transportation processes must always be taken into account within a company's growth plan, an aspect that is sometimes left behind by the constant occupation or focus on mission activities, compliance with deadlines and other day-to-day activities that ultimately result in the businessman's neglect of non-quality costs (Pérez and Barrera, 2017).

One of the alternative solutions, faced with the Latin American logistics panorama, that experts in the area have suggested, is found in the immersion of technological tools that provide control and programming of vehicle systems in real time and that also facilitate remote verification through devices such as vehicle sensors, so that decision-making is supported with instruments in accordance with current reality and seeking to also provide a valid basis for assertiveness, taking into account the different factors that impact on high operation and maintenance costs (Bankinter, 2011).

New technological trends provide great advances that allow the use of smart devices or what has been called IoT, using reliable communication networks and providing updated information from anywhere in the world (Tiwary, et al., 2018). There are many success stories that are exposed in recent literature and that have even been patented in developed countries such as the United States, the United Kingdom and Spain (Hanson, et al., 2020); the above shows that not only can monitoring be done, but orders can also be programmed and executed with remote work, making companies more competitive, while reducing a high percentage of unproductivity (Nakandala, et al. 2016) (Malladi and Sowlati, 2018).

How much would be saved in Colombia and Latin America in terms of unproductivity costs and inadequate management, if the IoT trend or strategy were used? In relation to this, the logistics cost of products developed in small and medium-sized enterprises (SMEs) in Latin America must be considered as a factor that requires full attention to achieve better financial profitability. To do so, a detailed analysis is needed of the tools that propose better measures of logistics performance and resource management within one of the parts of the value chain, such as transportation and its relationship with IoT and information management (Ramírez, 2018).

The main objective of this research aims to carry out a descriptive and traceability analysis of the IoT through the case study of a fruit transport company located in the city of Barranquilla (Colombia), whose results make it easy to visualize the importance of elements such as: sensors, applications and similar components, in improving the quality of transport processes, and also favor aspects associated with maintenance and programming, of highly important processes such as cargo movement.

It should be noted that the movement of vehicles is a variable that significantly affects the decisions of transport companies and, due to the lack of information from studies related to this topic, there is a need to expand knowledge regarding the opportunities that can be derived from IoT for the benefit of business development, especially in the logistics sectors. The above can help with the management of fundamental programming and management factors, such as the types of devices to be used, systems with the greatest impact in terms of cost/benefit, among other elements of interest (Xiang, et al, 2020).

For the above reasons, it is expected that this document will serve as a basis for future studies, with the intention of providing information for the design and conceptualization phases, associated with topics of analysis of variables for improving load performance. According to the above, several recent supports are presented on the aspects that concern the topic under study; for this purpose, a review of academic and business publications was carried out, in order to identify the development and evolution of the topic within the research panorama. Thus, in Table 1 the contributions and methodological development of each case can be observed in detail.

Table 1: Contributions from the review of publications related to IoT and transportation

Name of the study	**Contributions/observations**
IoT platform for remote tracking and monitoring of vehicle parameters (Jacobo, et al, 2020).	The study focuses on the description of a web-based platform that allows tracking of different parameters of a vehicle during its movement. The device used is a GPS Tracker for data processing. Among the results delivered are the design of the software interface, parameters to be measured such as speed, acceleration, braking, rpm, lane change, turns, among others, and georeferencing data to

Name of the study	Contributions/observations
	support other related processes.
Design and implementation of a sensor network based on IoT protocols for monitoring goods (Gómez, 2020).	The project aims to design two types of monitoring devices for containers and goods, seeking to reduce the percentage of products in poor condition that reach the final route. The designed system measures temperature and humidity and includes information on shipments containing containers and location, which are stored in a cloud for proper analysis. The results show the validation and testing stage, where correct connectivity, GPS position with frequent updates, and successful battery testing with a capacity of 11,400 mAh were deduced.
Proposal for an IoT and Telemetry Application Model in Workshop Service Processes for Automotive Dealership Companies (Gaitán, et al, 2018).	The study analyses a workshop as a work scenario, with sample processes such as appointment booking, vehicle reception and spare parts supply. A mixed analysis of the variables was carried out and a solution was proposed, including Internet of Things technology and telemetry. The study shows as a result the economic design of the device, application model for each of the three processes, vehicles required by the model and recommendations.
IoT solution for intelligent analysis in grape production (Barriga, 2019)	Through this thesis, the need for resource optimization within the grape industry to predict production using intelligent data capture systems through the Internet of Things is evident, for monitoring processes and analyzing digital images, obtaining variables such as the ratio of grapes and leaves. The designed system

Name of the study	Contributions/observations
	uses linear regression models to predict crop evolution, but to do so requires measuring and monitoring crop and environmental conditions, and other parameters in detail.
Smart parking with IOT (Calot, et al, 2017).	This document describes a system that operates with the Internet of Things, to manage a parking lot, through sensors and wireless networks, in addition to digitizing the information and communicating it to the interested parties, especially the driver, where he can receive advance information about available parking spaces, and other services such as car washing, maintenance, among others.
IOT technologies within the connected industry: Internet of things (Cruz, et al, 2015).	This book describes the uses of IoT technologies within the global industry. Among the results, it is found that the benefited areas have been laboratories, improving the validation and assembly of objects, electronic design, in the generation of new interconnected objects, mechanical design, for packaging, boxes, covers, embedded systems, programming of new digital information platforms, networks and integration of different industrial areas, tracking through sensors, actuators, among others.
Design of a logistics management model for retail companies based on the Internet of Things (IoT). Case study: a company from the province of	The thesis proposes the design of a model that can be applied to the Retail industry, using a mixed methodology and analyzing standard processes in the SCOR supply chain and through the use of an Internet of Things (IoT) device for automation and monitoring in a real way. As

Name of the study	Contributions/observations
Esmeraldas (Cárdenas, 2018).	a result, the phases, procedures, and personnel involved in the implementation process within a company (case study) in the province of Esmeraldas, Quito, with several deficiencies detected within the work chain, were delivered.
IoT applications for vehicular congestion control (Camarena, et al, 2018).	The referenced article shows a compilation of different technologies that have been developed and applied to the problem of vehicle congestion. The result is prototypes such as Road Runner, Road Pricing, Smart Traffic Lights, Signal Guru, and Parking Systems, each with features that contribute to reducing congestion depending on the user's needs. All technologies have variations in the way they operate and some provide maps.
IoT-based real-time monitoring and video surveillance of mass transportation units (Aguilar, et al, 2019).	This document contains essential information about an IoT-based monitoring and video surveillance system designed for an applied case study: public transport service provided at the Technical University of Ambato where the Internet of Things is used and data on journeys and location is recorded, in addition to other control tools. A mobile application is used to interconnect students and university staff. The designed system uses work tools such as GPS, and for security cases it also uses systems that include communication strategies including a panic button.
Internet of the Future – Study of IoT technologies. (González, et al, 2020).	The article highlights the main IoT applications and technologies in the form of a report. Among the results found, it is indicated that

Name of the study	Contributions/observations
	IoT work elements used to be small pieces, but are now more complex and have better capabilities. The research is exploratory in nature and analyzes 58 bibliographic sources and works under a preliminary map that addresses the study in depth, verifying opportunities, challenges and research needs.
Development of an IoT control prototype to monitor vehicle fuel supply (Díaz and Zambrano, 2019).	This research project develops a monitoring system for the fuel supply process through the use of the Internet of Things. To do this, a sensor and the use of the Full True platform are proposed, where the client can compile and record information and has access to indicators such as the ratio of actual fueling to paid fueling..
Design of an intelligent monitoring, administration and collection system for public transport (Patiño, 2017).	The article studies the fleet and collection processes for public transport companies in Medellín and the Aburrá Valley (Colombia) and proposes an integrated technological platform for its management as a solution model, presenting the design phase of the prototype.

Source: Prepared by the authors.

2. The model

In this section, a descriptive and IoT traceability analysis is carried out in the city of Barranquilla and focused on measuring the vehicle and cargo conditions of a fruit transport company. To do this, a data collection was carried out that allowed us to appreciate, in a summarized way, the operation of the CargoModal© tool (design function and other scheduled service and maintenance characteristics), directed towards the transport management and intermediation processes between the different cargo transport agents of the analyzed entity. Below is a list of the variables to be considered for the descriptive study of the CargoMo platform: Functional-Design (Rasberry device) and other characteristics (service).

Within the design, the CargoMo platform uses the Raspberry Pi B+ Leaf storage device, a portable board that acts similarly to a computer and stands out for its low acquisition cost. The Raspberry model in general has evolved its prototypes and versions, uses wireless connectivity via Bluetooth, is small in size and also portable. In relation to this, the Raspberry type B+ compared to the model A, is more didactic, in addition, for embedded projects, requires low power and provides more USB ports compared to the model B alone, as shown in Figure 1 (Zhao, et al, 2015).

Fig. 1: Raspberry conectado con diferentes puertos USB (Zhao, et al., 2015)

The Raspberry device can also be interconnected with several ports, log in from several laptops, in addition to the one that operates as an administrator; and, in terms of security, if one of the users logs in and fails more than three times, a message will be sent to the central administrator, the same measure that applies in the case of recognizing an intruder in the system. Based on the specifications, the architecture of the system can be seen in Figure 2.

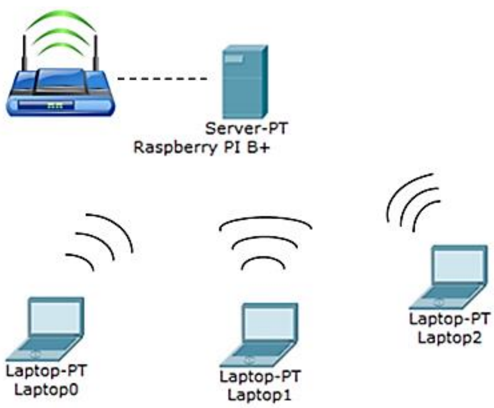

Fig. 2: Arquitectura del sistema utilizando conexión con Rasperry PI B (Zhao, et al., 2015)

As shown in Figure 2, the Raspberry Pi B+ is used as a server and is responsible for interconnecting several laptops or clients within the same network. They can communicate via Wi-Fi, calling it the client-server system; also via Zgbee (wireless communication) and localhost (central or local computer) (Zhao, et al. 2015). In the model designed within the CargoMo platform, the connection is made through a 3G SIM card, with a data plan.

Additionally, the Raspberry Pi 3 Model B+, applied in the study project of the fruit transport company, has in its latest version a 1.2 GHz 64-bit processor, with four ARMv8 cores; as well as an 802.11n Wireless Lan, Bluetooth 4.1 and Bluetooth Low Energy (BLE). Like its previous version, it has features such as 4 USB ports, 40 GPIO pins, full HDMI port, ethernet port, 3.5 mm composite audio and video combo connector, camera interface (CSI), display interface (DSI), MICROSD card slot, VIDEOCORE IV 3D graphics core, dimensions 8.5 cm by 5.3 cm (SINMAF S.A.S, 2018). Its purchase price is approximately 43 euros, of good quality and despite the fact that its rivals have 32 Gb, the other alternatives are more expensive and do not match the good performance of the product (Velasco and García 2020). Next, in Table 2 a detailed comparison of the advantages of the Raspberry Pi 3 Model B model in relation to other models is made.

Tabla 2: Comparativo de modelos Raspberry PI (Velasco y García, 2020)

Model	Version	Number of ports	Characteristics
Pi 1 A	First model	1	700 MHz 256 MB de RAM Card SD
Pi 1 B	Second model	1	700 MHz 512 MB de RAM Card SD
Pi 1 B+	Third model	4	Switch to Micro SD
Pi 2	Fourth model	4	Micro SD Top processor model 900 Mhz 1 GB a 2 GB de RAM
Pi 3 Model B+	Last model of version B	4	1 GB a 2 GB de RAM Wi-Fi + Bluetooth: 2.4GHz y 5GHz IEEE 802.11.b/g/n/ac,

Model	Version	Number of ports	Characteristics
			Bluetooth 4.2, BLE Micro-SD

Fuente: elaboración de autores con base en Cedeño & Zavala (2023)

As can be seen in the table above, the B+ version 3 model contains higher speed, different connection methods and a micro SD, which improves its performance by up to 8%. The connectivity power is undoubtedly faster than previous versions, it also differs from the Raspberry PI 3 or the PI 3 Model B+ due to the download capacity of the previous version for 94 WiFi 2.4 GHz 32 LAN, as for the latest general version 300 WiFi 2.4 GHz 40 LAN (Velasco and García 2020).

3. Results

The company in which the initial implementation is decided consists of a perishable products (fruit) transporter with distribution routes and cargo management between several cities, for which an alert generation service is required for faults located in the vehicles, whether corrective, preventive or predictive.

Within corrective maintenance, the technology and model of the vehicle are first defined so that the inspection board reflects through signals any change in the current state, in addition to the need to physically inspect. For this, the system uses color signals: yellow or orange to indicate caution or risk; red, to indicate a problem or situation that requires immediate attention; and green in relation to information signals. Additionally, among the required maintenance it shows the following: oil, battery, engine, temperature (among other essential components and of great impact for the operation).

Regarding the automotive body, the service is provided for LUV vans which can carry a capacity of up to 1000 kilograms transported and HNR trucks which can carry up to 1500 kilograms transported (SINMAF S.A.S, 2018). Regarding preventive and predictive maintenance, conditions are already programmed for generating alerts, in addition to taking into account the reading of the ODB knowing the operating parameters (SINMAF S.A.S, 2018).

Consequently, within the results, it is possible to establish that the functional requirements for the optimal operation of the model are met in the design of the dashboard, the colors; in addition to the technical specifications of the system that include a Raspberry 3+ rapid prototyping computer, an Ardafruit Fona 3G/GSM+GPS board, an LCD screen, an ODB II device, among other devices, such as connector cables, battery, antenna and adapters. On the other hand, it is worth highlighting other non-functional requirements that depend on the organizational requirements, such as the type of client, the characteristics of the organization, the type of quote made and the price agreed upon in the negotiations.

Regarding scheduling, for journeys of 5,000 km traveled, the system recommends actions such as: changing the engine oil, the air and oil filter, and topping up the fluid levels of the different systems of the car. For journeys of 10,000 km traveled, the system recommends actions such as: topping up the fluid levels, such as brakes, battery water, hydraulics, differential and gearbox; alignment and balancing; checking the tension and effectiveness of the brake pedal, the parking brake and the rotation of the wheels; checking the condition of the electrical system in general, oil leaks, condition of joints, ball joints and dust covers, intake system, pipes and hoses; repeating the review at 20, 30,000 and 100,000 kilometers; and performing a new alignment and balancing.

The above description presents two scenarios: the first consists of a descriptive study of the CargoMo platform through a review of functionality, analysis of the speed of the Raspberry device) and other annexed characteristics such as data storage. The second scenario is the one presented for scheduled service and maintenance, through the analysis of a specific case study of a fruit transport company with the creation of alerts on vehicle performance and work characteristics defined according to the type of company.

Thus, for the implementation, a CargoModal platform with computer technologies and connection to wireless networks that interconnect the main administrator and several operators is required (SINMAF S.A.S, 2018), in the control system. In the vehicle, process and testing sensors for obtaining data from the same machine or vehicle and to extract information related to it; also, test signals, installed in the equipment under special conditions, depending on the maintenance schedule (cracks, corrosion and wear).

Additionally, to capture data, it is necessary to define the equipment requirements, by the client and vehicle, hosted on the vehicle's Raspberry PI device, where the data is stored, synchronized and reported; in such a way that the sensors present in the measurement capture are identified and sent to the web service. In relation to the above, it is worth noting that the storage database used is called SQLite (SINMAF S.A.S, 2018). According to the records of the OpenDocument database (ODB), an open source program installed within the desktop of the fruit transport company in the case study, the behavior of the RPM, Load and Pressure variables is determined; from which figure 3 is derived.

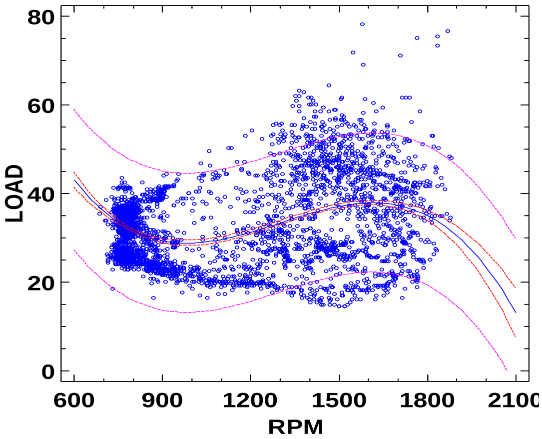

Fig. 3: Load Engine (Carga) VS RPM con base en SINMAF S.A.S (2018)

As can be seen in Figure 3, the variables Load Engine and RPM are related, which represent the engine load (capacity of the engine to generate energy) and the number of revolutions per minute. In this sense, it can be determined that, as the revolutions per minute are increased, the load is mostly unstable; that is, according to technical considerations, it is established that the cause is due to the speed and inclination of the vehicle studied; even so, the results obtained require a fault assessment SINMAF S.A.S (2018). On the other hand, when entering a third variable, identified as engine air and fuel pressure, also called Manifold pressure, and being compared with the two variables in Figure 3, it was determined that within the vehicle there is a close relationship between pressure and load; such that the RPM values obtained a more variable behavior.

Thus, the conclusions from the results of the variables analyzed allow us to establish that the device model, in this case the Raspberry model selected, constitutes an important decision, to the extent that one of the available devices has characteristics that affect the connection speed, costs, storage size, system performance, and card size.

Meanwhile, the behavior of the engine directly influences transport logistics and must be constantly verified; in response to this, within the maintenance it is necessary to make control charts that allow establishing the degree of variability of the data that, according to what is shown in figure 3, resulted in the value of the load being unstable. Therefore, one of the possible failures that can be found within an evaluation are usually related to lubrication, power supply, cooling.

Additionally, it is worth highlighting that the maintenance schedule to be performed, in kilometers traveled, corresponds to the type of vehicle, that is, its characteristics, such as model or engine capacity; Therefore, the design of this work structure must be carried out in a customized way, as occurred in the application analyzed in a fruit transport company. Consequently, it was possible to show that, from practice, other conditions such as the state of the roads in aspects related to tires, gasoline consumption, among others, had an impact.

On the other hand, it should be noted that the lubrication process allows the absorption of dissipated heat and eliminates lost work due to greater movement in the system where friction exists; thus, the energy supplied allows the engine to operate in optimal conditions, hence cooling must be essential to maintain adequate temperature levels. Finally, it is worth highlighting that there are different types of combustion engines and, consequently, within the maintenance, the specifications of the model, related to cooling, operation, type of truck, transport routes that interfere with wear and weight must also be taken into account.

4. Conclusiones

Although Xiang et al. (2020) present the use of piezoelectric sensors for the detection of mobile loads on pavements, demonstrating high precision in real-time measurement and monitoring, which is crucial for predictive maintenance. After having carried out the corresponding evaluations of the characteristics of the CargoMo platform, it can be concluded that it is indicated for the improvement of the transport performance of the analyzed company, since it demonstrates the ability to solve problems under pressure or stress, considering that it already has a maintenance schedule, not only corrective, but also preventive and predictive, which allows detecting failures ahead of time. This platform has a state-of-the-art device that works as a computer, called Raspberry Pi 3 Model B+, which is characterized by being economical and fast and whose version has differentiating and innovative elements, such as a micro SD card, access to Wi-Fi and Bluetooth, four ports, interconnection between one or more operators and a performance greater than 8%.

Other variables analyzed highlight that the use of georeferencing data provides greater reliability for the client, facilitating the location of the load, the solution to the transportation needs and the analysis of the processes in real time, in relation to the characteristics of the vehicle. The above is of great importance, as it contributes to greater customer satisfaction, which in turn translates into word-of-mouth recommendations, increasing the probability of closing future contracts with new clients through the use of this platform; in addition to other benefits such as customer data records through requests, quotes, documents, performance monitoring.

Finally, georeferencing tools fulfill a fundamental task, insofar as they can communicate fundamental data, using the Internet as a basis for communication. It is important to know aspects such as the weather, the state of the load, the vehicle and the roads, which can only be achieved through the Internet of Things, which also analyzes in detail the variables that affect the aforementioned aspects; In this way, decision-making is closer to reality, reducing the levels of uncertainty, taking into account fundamental aspects that should not be overlooked and that are only received through monitoring and control; consequently, the analysis of the applied model allows us to verify that communication is easier with technological tools such as the Internet of Things.

*This work is derived from the Caribbean Logistics and Ports Research and Innovation Program. It was funded by the Science, Technology and Innovation Fund of the General Royalties System, Department of Atlántico. BPIN: 2012000100191, agreement: 0103*2013*000016. UN-OJ scholarship contract-2014-26010 UNINORTE - LOGPORT

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