IoT system for the validation of conditions in shipping couriers

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***Abstract*— Online activity has increased over the years and has become a staple in modern society. With it, online shopping businesses have become more common, as well as the number of Internet of Things (IoT) devices. As the shopping experience becomes less personal, some people try to exploit the system causing online businesses to increasingly suffer from return frauds. This paper proposes a solution to this problem, integrating IoT and image processing. The proposed system uses IoT to verify package conditions in courier services, and a database to monitor shipments. To develop the system, a literature review is conducted in order to understand what has been done in the area of logistics services. The literature review is also extended to projects that integrate image processing techniques with IoT to determine what tools are used in the development of these projects. Furthermore, the methodology employed for the development of the system is described. This includes the research models, research questions and hypothesis.**

Keywords—IoT, Image Processing, Courier Services, Package Monitoring

I. INTRODUCTION

In today's era, online engagement has grown significantly [1] and has become a staple in modern society. Online classes have higher enrollment numbers [2] due to hybrid solutions between online and offline learning. Online dating has become a common practice [3], with 30% of single adults of the United States and 25% of young Europeans reporting using dating applications.

E-commerce, defined as the exchange of tangible and intangible goods which includes all aspects of the trade process such as online marketing, ordering, payment, and delivery [4], has grown gradually over the years [5], making online shopping increasingly common [6]. Online shopping businesses rely on delivery services to distribute goods to their customers. Delivery services industry represents $1.4 trillion, or nearly 11% [7], of the United States (US) Gross Domestic Product (GDP).

A good shipping service is critical for a consumer, as evidenced by research [8] [9], which found that shipping is the most significant part of online shopping for customer satisfaction. Within the delivery process, package handling/condition is a make-or-break factor for online retailers. Study [10] confirms that the condition of the package delivered (if it's damaged or not) is of utmost importance for customer satisfaction. Furthermore, research [11] of users' review comments revealed that inadequate handling of goods is the most frequent topic.

Online engagement has driven the number of Internet of Things (IoT) devices up as well, a growth of 150% from 2017 to 2020 [12]. IoT is a global network according to standard and interoperable communications protocols, in which devices, physical or virtual, are connected to each other and integrated into the information network [13], with various applications in everyday life like cities [14], emergencies [15], agriculture [16][17], homes [18][19], healthcare [20][21], retail and logistics [22], and much more. IoT has a lot of potential to create solutions to problems never fixed before, like poor handling of delivered goods and improving quality of life.

A. Motivation

When a product delivered is reported damaged by a customer and the customer wishes to return it, it triggers a multistep process of handling that product, also known as Reverse Logistics (RL) [23] in the Supply Chain Management (SCM). SCM [24][25] refers to the coordination of material and information flows between installations of suppliers, manufacturers, and distribution. These three installations also compose the main stages of SCM: supplying, manufacturing and distribution. Additionally, customers can also be considered as a stage since information can flow in the form of customer feedback. RL is the backwards flow of materials and information in SCM, to a point of recovery or suitable disposal [26], as opposed to Forwards Logistics (FL). FL is the forward flow of materials and information in SCM, to a point of delivery to a customer.

Damage caused to a product can occur anywhere along the line of FL, however for courier services, their responsibility for the package lies within the distribution stage. For a delivery service to be liable for package damage, it means that the package was damaged during delivery.

Considering that the package wasn't damaged before distribution, it leaves only two possibilities: The delivery driver damaged it, or the customer did. This becomes a case of good faith, and without any compromisable proof to settle the dispute, return policies cannot be enforced, leaving the business with a tough decision: deny the return and leave the customer dissatisfied, or allow it and lose out on revenue. This is a global issue, research studies demonstrate that in the clothing industry 50% of returns are fraudulent, and 8% of all returns in North America are fraudulent, rendering return policies useless [27].

IoT is utilized to improved various aspects of modern life and can be very important for the development of solutions to unresolved problems in a variety of fields, including retail and logistics. A system based on IoT could be crucial to support delivery businesses with fraud returns, or at very least validate the transportation conditions under which products are delivered. This system could prove beneficial for both consumers and businesses.

From a business standpoint, courier services are the ones that stand to benefit the most from the system previously described. The system can offer non-repudiation as it validates the state of the product before it is delivered to the customer. This means that if the customer attempts to return a product due to mishandling, the system can provide proof to enforce return policies. With this improvement, courier businesses may reduce revenue lost on returns while maintaining customer satisfaction. Aside from that, data collected by the system can serve as a monitoring tool. For example, if a driver has a high rate of damaged packages, it may indicate poor driving. Given the number of packages delivered per day by courier services [28], that data can be used as a measure of a driver's performance.

The system's non-repudiation also extends to customers. For example, if a product is delivered damaged, the system will recognize it as such, meaning that the customer would be in their right to return the item. The monitoring of drivers also benefits the client indirectly since it assures proper delivery by serving as a deterrent to improper driving.

B. Context

Delivery companies' success relies on their customers. Developing ideas that improve delivery, correlates directly with customer satisfaction, which correlates with the success of the company. Some studies have been conducted to improve logistic services employing IoT.

Study [29] employed REDTags, an IoT-enabled device network that allows delivery service personnel to verify the status of a product at each step of the delivery process.

A framework was built to track and monitor the items, with back-end features for smart data transmission, administration, storage, and analytics. The framework provided a dynamic view that was suited to individual stakeholders, allowing for instant feedback and model changes. Machine learning was used to predict potential damage of items packaged, yielding good results. However, attaching these tags to each package can be time consuming, and verification in bundled packages may not be possible.

Another study [30] used a programmable IoT system with a decentralized based blockchain platform to track logistics in real-time and assure package safety and quality. The system was equipped with various sensors that recorded temperature, light, humidity, vibration, and geo-position. Radiofrequency identification (RFID) and QRcode technologies were also utilized for stakeholders to interact with parcels in transit. By adding more sensors, the platform could be expanded to transport new data, and an open data API was proposed to provide customers with product history.

These studies highlight the importance of IoT for the development of new solutions in the logistics services industry. These two topics, IoT and delivery services, are the ones covered in this paper.

C. Objectives

The main goal of this study is to implement a system that can validate the conditions of packages into courier services, using IoT. The system can then be integrated into transportation trucks of delivery businesses, helping the business reduce fraudulent returns and, simultaneously help customers ensure a return if they are properly entitled to.

A complementary goal for this study is to use the data acquired by the IoT system as a monitoring tool for driving during transportation. Too many damaged packages might be an indicator for poor driving; by identifying this behavior, businesses can limit the number of damaged deliveries and inform drivers of the problem.

II. EXISTING THEORIES & PREVIOUS WORK

This chapter focuses on reviewing studies related to the topic of the paper. The review will provide information on relevant methodologies as well as what has and hasn't been done in this field of expertise. The chapter is structured into four sections.

In section A., studies identified in a systematic literature review will be meticulously described. This section will provide knowledge about where innovation can be achieved.

Section B. briefly details projects involving IoT and image processing. These techniques may prove useful in the paper's solution, so a review of publications that incorporate it may prove beneficial.

Finally, a summary of the studies encountered and reviewed is present in section C., to organize all the techniques, protocols, equipment, and so on in the studies reviewed.

A. Related Work

This section describes studies linked to the paper's theme, which is the usage of IoT for the improvement of cargo conditions in logistics services.

1) REDTag: A Predictive Maintenance Framework for Parcel Delivery Services.

REDTag Service [29] presents an IoT-based, big data analytics prediction framework adapted to logistics services, to track the condition of transported goods and to early predict potential damages. It uses REDTags, which are smart ad-hoc hardware tags, attached to each package.

The tag is an IoT device containing sensors, batteries, memories, a processor, and a networking module to communicate with external mobile devices, using Near Field Communication (NFC). The device can be fitted with a variety of sensors, such as temperature, humidity, and location, to log a variety of events, like falls or collisions.

The framework consists of front-end and back-end services to store, manage, and analyze REDTag data. It relies on Big Data architecture to store data, as well as a machine learning element to predict potential breaks. Fig. 1 illustrates the proposed framework architecture.

The data and predicted results are shown on dynamic and customizable dashboards, allowing monitorization of packages and quick intervention. Clients can also be alerted of where, when, and who caused damage to packages, motivating drivers to be careful.

2) Logistics tracking system based on decentralized IoT and blockchain platform.

Midaoui et al. [30] provides a solution for a logistics tracking system that combines IoT and blockchain technologies. IoT is utilized to monitor the quality of the products, and the blockchain service is used for data storage and transmission.

The IoT architecture employed in this research is made up of three important modules: Sensor, Connectivity, and Processor. The sensor module contains the light, humidity, temperature, and vibration sensors required in the architecture. To scan RFID tags and identify packages, the connectivity module includes an RFID RC522 tag writer and RFID tag, as well as a 3G modem for communication with the blockchain platform. The processing module is a Raspberry Pi 4 Model B that connects the two modules and processes information.

The sensors enabled and their respective thresholds are based on the goods transported, and obtained by the Raspberry Pi, that fetches a configuration from the blockchain server. These configurations are agreed upon by the logistics services. The system transfers data when a threshold is surpassed, or a certain amount of time has elapsed.

The blockchain platform collects and stores the information received by the IoT system, so it may be displayed in the future. This technology is used due to being a transparent and secure service that ensures data trust and immutability.

3) Real-Time Monitoring via Patch-Type Piezoelectric Force Sensors for Internet of Things Based Logistics.

Chuang et al. [31] suggest the usage of patch-type piezoelectric force sensors that can determine if a parcel has been opened and/or damaged. These sensors release electric charges when mechanical tension is applied. If the parcel is opened, tensive stress is produced, and compressive stress if the parcel collides.

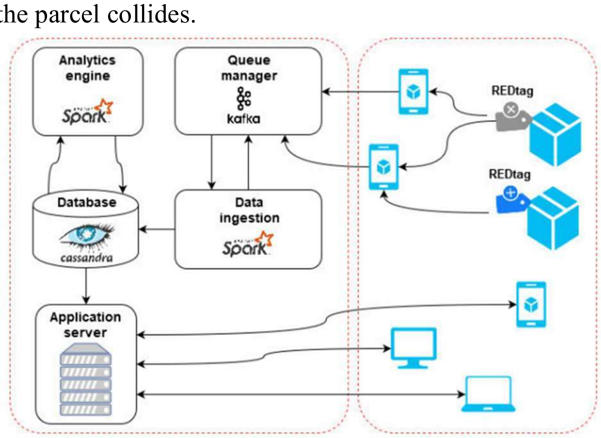

Fig. 1. Framework architecture of REDTag Service [29]

A prototype featuring a microcontroller unit was created so that the analog signals from the sensors can be transformed into digital signals. The digital signals are transmitted via Bluetooth by the microcontroller. Bluetooth was adopted because it's low-cost, low-power, low-interference, and a protocol easy to implement.

Transportation vehicles receive the sent signal through their infotainment system using an application developed, iTape. iTape, shown in Fig. 2, analyzes and monitors the data so that it can be uploaded to a cloud database via 3G/4G communication. The database, presented in Fig. 3 keeps note of the occurrence's time, type and location of the occurrence, so that it may be monitored in real time.

4) SafeTrack, an intelligent model for logistics management.

SafeTrack [32] is a logistics management model that uses geofencing algorithms, RFID technology, and commercial mobile devices. SafeTrack automates: delivery management without user interaction, detection of irregularities in real-time, such as erroneous deliveries or cargo thefts, and monitorization of detours in planned routes. To do this, a component is attached to the rear of the truck with an RFID shield that detects when parcels pass over the RFID reader.

The model provides a website that authorizes administrative functionalities as well as view features for monitored mobile devices movements. It also enables real-time monitoring of ongoing travels and the occurrence of alerts due to detours, low battery, and delivery status, as shown in Fig. 4.

Package monitoring is accomplished by implementing the *SafeDuino* component, RFID tags, and *SafeTrack Mobile* application in vehicles, as shown in Fig. 4. RFID tags are placed in packages so that they can be traced, and in trucks so that they can be tracked as they enter or depart an installation. The vehicles also signal their position via the Global Position System (GPS) component.

Fig. 2. iTape [31]

Sensor Number	Time	Event	GPS
dsfafas132	2015-11-28 20:18:09	Tear Off	
dsfafas250	2015-11-27 18:34:50	Tear Off	
dsfafas186	2015-11-27 16:58:40	Fall Down	
dsfafas943	2015-11-26 19:48:27	Tear Off	
dsfafas751	2015-11-25 11:17:35	Fall Down	
dsfafas483	2015-11-25 09:23:45	Fall Down	

Fig. 3.Cloud database [31]

	ID	Travel	Driver	Alarm	Date	Severity
View	45	Palmeira-POA	Rodrigo Remor Oliveira	WARNING!! The device's battery is low !	16/12/2011 16:09:00	Low
View	45	Palmeira-POA	Rodrigo Remor Oliveira	WARNING!! The device is leaving the planned route!	24/11/2011 23:14:20	High
View	45	Palmeira-POA	Rosana Salete	WARNING!! The device is leaving the planned route!	24/11/2011 20:10:40	High
View	45	Palmeira-POA	Rodrigo Remor Oliveira	WARNING!! The device's battery is low !	23/11/2011 23:14:20	Low
View	45	Palmeira-POA	Carlos Emir	WARNING!! The device is leaving the planned route!	23/11/2011 18:30:16	High
View	45	Palmeira-POA	Rodrigo Remor Oliveira	WARNING!! The device's battery is low !	23/11/2011 14:10:30	Low
View	45	Palmeira-POA	Rosana Salete	The device is shutting down	23/11/2011 12:40:10	High
View	45	Palmeira-POA	Carlos Emir	WARNING!! The travel was initialized out of the estimated date!	22/11/2011 16:10:00	Medium
View	45	Palmeira-POA	Rosana Salete	The device is shutting down	20/11/2011 17:09:00	High

Fig. 4. Website Monitoring and Management [32]

Package monitoring is accomplished by implementing the *SafeDuino* component, RFID tags, and *SafeTrack Mobile* application in vehicles, as shown in Fig. 5. RFID tags are placed in packages so that they can be traced, and in trucks so that they can be tracked as they enter or depart an installation. The vehicles also signal their position via the Global Position System (GPS) component.

SafeDuino is made up of an Arduino, a Bluetooth module, an RFID reader and a rechargeable battery that is recharged via vehicle's 12 volts sockets. This component reads RFID tags on packages, but it can't tell whether they're being delivered or deposited. The *SafeTrack Mobile* app solves this problem. The Bluetooth module is used to communicate between the app and the *SafeDuino*.

The *SafeTrack Mobile* app keeps track of shipments and determines if they are being loaded or unloaded. This application operates in the background on a mobile device and feeds information to the *SafeTrack Server* which is done by General Packet Radio Service (GPRS) using Simple Object Access Protocol (SOAP).

The app has two approaches for the loading/unloading problem depending on the number of antennas used. For the single antenna approach, the app recognizes entering or leaving by verifying if the RFID tag has been entered before. For the two-antenna approach, one of the antennas is positioned farther inside the truck. The order which by the antennas scan the RFID tags determines the loading or unloading of the package.

Fig. 5. Carrier station architecture for the deployement of *SafeTrack* [32]

5) RFID GPS and GSM-based logistics vehicle load balancing and tracking mechanism.

Prasanna and Hemalatha [33] propose a system that prevents truck overload, delivery tracking, and detects incorrect delivery of goods. This is achieved with a Peripheral Interface Controller (PIC) microcontroller that contains the followings components: RFID, GPS, Global System for Mobile (GSM), Weight Sensor, Keypad, Alarm, and Liquid Crystal Display (LCD).

The products in the vehicle are tracked and monitored using RFID. Each package is equipped with an RFID tag and the transport truck is equipped with an RFID reader. The driver must read the tag and enter a code into the keypad before delivering it to a customer. If the code is correct, the package can be unloaded; otherwise, the alarm is triggered, and the LCD displays a message.

Vehicle load management is accomplished through the usage of a weight sensor. The sensor registers the weight inside the transport vehicle during loading, and if the threshold value is exceeded, the alarm in the microcontroller buzzes. The threshold value is assigned previously in the microcontroller. GPS and GSM are used for tracking.

6) Hybrid Cargo-Level Tracking System for Logistics.

Yang et al. [34] developed a hybrid system that combines various types of positioning and communication technologies, and infrastructure-based and infrastructure-less position methods. This system improved availability, accuracy, and overall cost.

The hybrid system offers infrastructures for data transferring and positioning to the tracking devices. These devices acquire data for position computation and environmental sensing, and then transmit the data to a server through the infrastructure provided. After that, the server determines the position of the devices and delivers it to the tracking applications.

The hybrid system offers two types of hybrids. The first hybrid employs GPS, WiFi, ZigBee and RFID for wireless positioning, while GSM, WiFi and Zigbee are used for communicating. The second hybrid leverages existing infrastructure-based and infrastructure-less position technologies in a complementary manner to reduce expenses.

Two types of tracking devices are used in the system. A full-function device includes GPS, WiFi, motion sensor, ZigBee, and an RFID tag, allowing infrastructure-based positioning and also infrastructure-less positioning as an anchor node. A dummy device is equipped with a motion sensor and ZigBee and only supports infrastructure-less positioning; thus, tracking can only be performed with the help of a full-function device.

The intelligent tracking devices have a modular design that allows greater versatility. By removing modules from a full-function device, it can be turned into a dummy one. The devices work for weeks and even months due to power savings of the hybrid design. Furthermore, the devices only update their position when motion is detected.

The server offers services related to the development of smart logistic tracking apps, allowing customers to develop tracking apps that match their needs.

7) eTracer: An Innovative Near Real-Time Track-and-Trace Platform.

eTracer [35] is a platform designed specifically for courier companies that allows near real-time end-to-end monitoring, detection, and tracking of products in transit. It works with a variety of carriers and forms of transport, improving real-time management in the SCM.

eTracer combines RFID tags with telematics and wireless technologies to collect a variety of information. To obtain this information, eTracer employs various technologies, such as GPRS, GPS and RFID, paired with current protocols and standards, like Evolved Packet Core (EPC), Transmission Control Protocol/Internet Protocol (TCP/IP), Bluetooth and Wireless Local Area Network (WLAN).

RFID tags are attached to parcels. The tags are configured with an RFID reader and an eTracer specific portable equipment. A GPS receiver in the equipment gathers and transfers necessary data for the package's position via GPRS. Vehicles are equipped with RFID readers to detect cargo during loading. These cars also have a GPS receiver and GPRS wireless transmitter to always broadcast their whereabouts.

Logistic facilities have RFID readers positioned in entrances so they may detect packages being moved within the facilities. The data obtained is stored in a local web server through WLAN, which is transferred afterward to the eTracer main server. This server also receives data acquired by the portable equipment through GSM or GPRS.

eTracer stores the data in a relational database so that authorized eTracer users may obtain real-time, automatically updated, and organized information about the timing and position of their deliveries. The eTracer architecture is represented in Fig. 6.

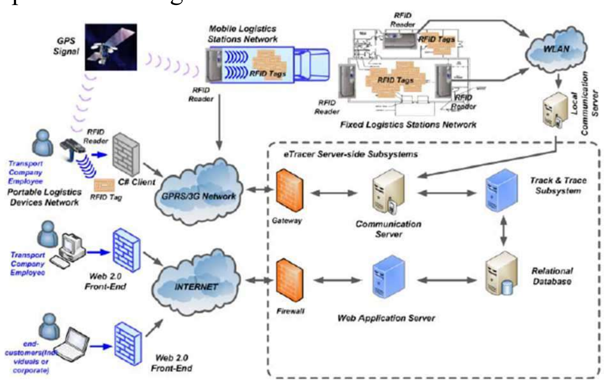

Fig. 6. eTracer platform architecture [35]

8) A Remote Monitoring System of Logistics Carrier Based on Wireless Sensor Network.

Wang [36] developed a wireless sensor network (WSN) and GPRS communication-based remote monitoring system. The system is composed of three parts: Wireless sensor network, GPRS transmitter, and a monitoring center. The system's architecture is represented in Fig. 7.

The WSN is mounted in transportation vehicles, and is composed of a ZigBee microcontroller unit, wireless sensor nodes, RFID readers, and a GPRS wireless communication module. Sensors are utilized to gather data about the conditions inside the vehicle and to monitor driving, as ways to ensure package safety. RFID tags are attached to the packages and are scanned automatically by the RFID readers.

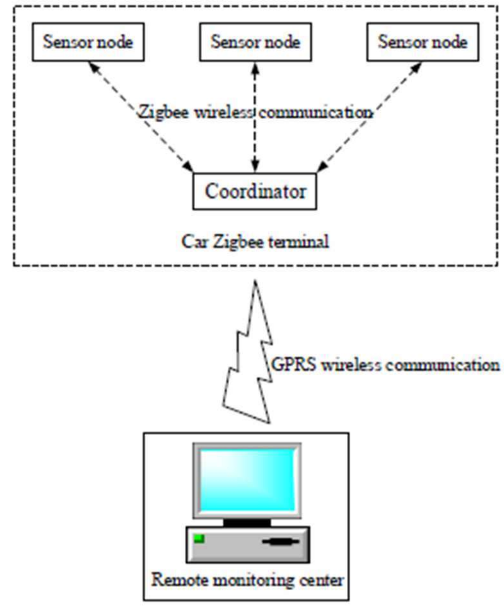

Fig. 7. Remote monitoring system architecture [36]

The information acquired by the sensors is transmitted via ZigBee, and then transmitted to the monitoring center via GPRS communication. The monitoring center analyzes the data received and sends instructions to the vehicle, monitoring it in real-time.

To guarantee optimal conditions during transportation and ensure package safety, the following sensors are utilized: temperature, humidity, brightness, and infrared. Temperature and humidity sensors are employed to collect data on the conditions within the vehicles. The brightness sensor determines if the truck's door has been opened, and the infrared sensor detects whether someone is inside.

B. Image Processing and IoT

This section reviews research regarding the use of image processing techniques in IoT.

Dubey and Damke [19] created a non-contact baby monitoring device that detects crying, movement, and position of the infant. A Raspberry Pi 3 Model B+ was used, together with a sound detection sensor module and image processing, to achieve this. To implement image processing the Raspberry Pi camera must be setup so that the baby's head and body are centered. Furthermore, the raspberry operating system and the packages OpenCV, Numpy and a virtual environment must be installed. The system was trained using a Haar cascade classifier paired with a dataset of positive and negative images of a newborn doll. When the system detects the infant's motion, it sends an alert via e-mail to the system's user.

Where's The Bear? (WTB) [37] is a system that combines cameras, edge clouds, and a back-end cloud to automatically categorize animals in images captured by the system using machine learning-based image processing. WTB employs techniques to decrease resource waste. First, animal classification is done on-site, which reduces the amount of bandwidth required. Second, training data was created by combining backdrop pictures taken at the reserve with images of animals obtained from Google Images, decreasing bandwidth requirements once again. Third, the model is trained on the cloud before transferring it to the on-site system, requiring less processing power. Animal classification was accomplished using Google TensorFlow and Open Computer

Vision (OpenCV) Optical Character Recognition (OCR), which correctly categorized 87% of produced photos and 94% of real images with a 0.90 certainty or better.

Kapoor et al. [38] describes a method for determining variables that hinder plant growth with the combination of IoT and image processing. This work utilized soil moisture, temperature, and humidity sensors paired with a Serial JPEG camera module and an SD card assembled on an Arduino UNO. The camera snaps photos of crops at regular intervals, which are analyzed to identify morphological changes, and the farmer is notified if they are hazardous to the plant's growth. The image is processed by MATLAB algorithms that are trained with a dataset of pictures previously taken. The algorithms consider not just the picture, but also the environmental conditions and fertilizers.

A very similar study [39] also employed MATLAB algorithms to detect changes in plants. In this study, the IoT system incorporates sensors and a camera assembled in an Arduino. Factors like temperature, humidity, and color, shape, texture, and area of the plant are all considered. MATLAB segments the image, performs edge detection, and analyzes the plant for illnesses. Based on the analysis given by the algorithms, pesticides may be applied by the IoT system according to the disease diagnosed.

A smart city solution to overcome the impact of traffic congestion is suggested in [40]. It proposes an IoT system that can measure traffic density based on real-time video and image processing techniques. It employs a Raspberry Pi, a cloud server, and MATLAB. The objective is to determine traffic density on both sides of the road and give the user the ability to control the traffic signal. The solution was achieved by calculating the difference between a reference image, that corresponded to an image of the road without traffic, and images in real-time. This calculation was performed by the Raspberry Pi using image processing techniques available in MATLAB. Furthermore, since color is not important for this process, the image calculated is converted into grayscale and binarized to improve performance.

Sharma et al. [41] suggests a smart city system based on WSN, Unmanned Aerial Vehicles (UAV), IoT, and image processing for early fire detection. Sensors are placed in regions of interest to gather environmental data. Temperature, humidity, light intensity, and smoke information are all collected in real-time by the sensors. Radio Frequency is used to communicate between sensors and to transfer data to the central node, while GPRS is utilized for communication between the central node and a cloud platform. The gathered data is stored in the cloud, where it is displayed and examined by MATLAB for abnormal events. In the occurrence of an abnormal event, the control station is notified, which triggers the UAV to acquire photos of the location. The sensor's GPS coordinates are used to determine the location. The image taken is processed to detect potential fires.

Rane et al. [42] designed a system to validate and manage parking lots. Utilizing a BeagleBone Black microcontroller attached with a Raspberry Pi camera in the entrance, the system validates the entrance to parking spaces. A picture of the license plate is snapped, and the number is converted into text via OpenCV's OCR technique. The converted license plate number is sent to the server, where it's compared with the employees' registered license plate numbers. The server validates the entry in the parking lot, permitting it or denying it. An application is made available so that users can mark where they have parked their cars, and visualize spots taken.

C. *Summary*

The previous studies will be summarized in this section. To do so three tables were created. Table I summarizes the key features of the publications discussed in section A. It covers sensors utilized, equipment used and how communication was established.

TABLE I. SUMMARY OF THE STUDIES REVIEWED IN SECTION A.

Ref.	***Sensors***	***Equipment***	***Communication***
[29]	Temperature, Humidity, Location	REDTag	NFC
[30]	Temperature, Humidity, Light, Accelerometer, RFID	Raspberry Pi 4 Model B	3G
[31]	Piezoelectric force	Microcontroller unit, iTape	3G, 4G
[32]	RFID, GPS	Arduino	GPRS, Bluetooth
[33]	RFID, GPS, Weight	Keypad, Alarm, LCD, PIC microcontroller	GSM
[34]	RFID, GPS, Motion	Microcontroller	WiFi, ZigBee, GSM
[35]	RFID, GPS	In-house portable equipment	GSM, GPRS, Bluetooth
[36]	Temperature, Humidity, Brightness, Infrared, RFID	ZigBee microcontroller	GPRS, ZigBee

Table analysis reveals that RFID is very abundant in this sector. In the SCM process, RFID is routinely used to identify packages. Equipment and communication-wise presents more variety on what is used.

The tools used to implement image processing techniques are listed in Table II. All projects developed either use OpenCV or MATLAB for their image processing needs. On the one hand, most studies that integrated data sensing with image processing, such as [38], [39], [41], utilized the MATLAB software. On the other hand, studies that utilized only images for the development of their solution used OpenCV.

TABLE II. SUMMARY OF THE TOOLS NEEDED FOR THE STUDIES REVIEWED IN SECTION B.

Ref.	***Tools employed***
[19]	OpenCV, Numpy, Raspberry operating system
[37]	OpenCV, Tensorflow
[38]	MATLAB
[39]	MATLAB
[40]	MATLAB
[41]	MATLAB
[42]	OpenCV

Finally, Table III states the main contributions of the studies described in section A.

TABLE III. MAIN CONTRIBUTIONS OF THE STUDIES REVIEWED IN SECTION A.

Ref.	***Contribution***
[29]	Package break prediction based on machine learning, data-driven solution with integration of IoT and Big Data frameworks
[30]	Decentralized IoT/Blockchain-based platform to assure transparency and traceability to stakeholders in SCM
[31]	Usage of piezoelectric patch type force sensors that can detect opening or falling of packages to improve real-time monitoring
[32]	Automatic delivery management and an inconsistency detection mechanism in real-time
[33]	Avoiding weight overload of transport trucks and misplacement of packages
[34]	Hybrid system that utilizes infrastructure-based and infrastructure-less positioning techniques for cargo-level tracking
[35]	Providing courier businesses real-time end-to-end tracking of parcels
[36]	Remote supervision of delivery vehicles and transported goods

Many advances in the field of IoT-based cargo monitoring in logistics services have been developed, but few attempt to identify damage to carried products. Study [29] predicts potential damage based on data collected, and [32] recognizes whether a package has been opened or damaged. Other studies focus on tracking, and/or ensuring safe conditions during transportation with sensors.

III. METHODS

To accomplish the objectives established for this paper, a methodology was followed. This chapter describes the methods employed to ensure that the objectives are met. Section A. includes the research questions and hypothesis definition, Section B. explains the research model utilized, and Section C. proposes a model prototype for the IoT system.

A. Presented study, Research question & Hypothesis

It's critical to detect whether a package has been mishandled before delivering it to a customer to ensure that all parties are treated fairly. During the development of an IoT system that validates conditions in shipping couriers, the following questions are to be answered:

- How can the system verify the quality of the package before delivery?
- How effective is the system at detecting package damage?
- What further applications are there for the data acquired by the system?

Questions one and two are crucial for the fulfillment of the objectives of the paper. The first question is asked to determine what configuration of the IoT system can be used to verify package conditions. After concluding what configuration to employ, the system's success rate at detecting damage must be evaluated, which is why the second question is proposed.

The third question proposed isn't as important as the previous two. The system developed will acquire a large amount of data regarding parcel conditions, allowing the data to be used for purposes other than determining whether a package is damaged. This research question is complementary since determining applications for the data may improve the system created.

Hypothesis is defined to predict the answers to the research questions written down previously.

Regarding the first research question, to achieve verification of package conditions before delivering to clients, the system configuration should include a camera so it can take pictures before delivery. The camera is connected to a microcontroller that can activate/deactivate it to save battery life. This microcontroller is paired to a network module to transfer the information collected to a database. The database is necessary to store the data and monitor the deliveries. Besides that, the microcontroller should include sensors for tracking.

For the second question, the system aims to correctly identify and verify the conditions of all packages transported, which translates to an efficiency of 100%.

Finally, concerning the third question, the data acquired is going to be utilized as an evaluation tool for the transport trucks drivers' ability. If the system detects too many occurrences of damage, it could indicate poor driving by the person behind the wheel.

B. Research Model(s) & Instrument(s)

The research model "Designated Science Research Methodology (DSRM)" by Peffers at al. [43] was followed for the development of the suggested work. This model is compromised of six stages as is shown in Fig. 8.

The first stage of the process was already complete in the *Motivation* section, where problems were identified, and motivation was given.

The formulation of objectives for a solution, which makes up the second stage, is declared in sections *Presented study, Research question & Hypothesis* and *Objectives*.

The next stage is designing and developing the artifact. The architecture and functionality shall be decided in this stage, after which the solution will be developed depending on the established objectives. For this paper, this phase will consist of designing the IoT architecture and functionalities that will be required to validate package conditions.

Once developed, the solution will be put to the test. In the fourth stage, a demonstration will be performed by the artifact to solve one or more instances of the problem. For this study, the IoT system will attempt to verify the conditions of a parcel.

Evaluation of the artifact's efficiency happens in the fifth stage. Results are analyzed considering the objectives formulated previously.

The suggested solution in this work will be evaluated based on whether it can verify package conditions, as well as its consistency. The artifact's results can also be compared to artifacts of related works.

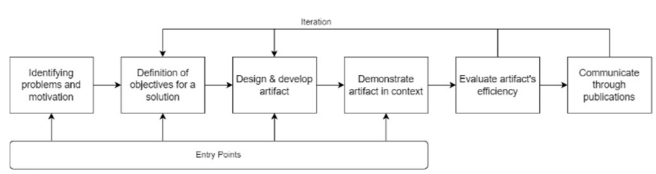

Fig. 8. DSRM process [43]

The final stage consists of communicating the problem and its importance, as well as the artifact via academic publications.

Stages two and three can be iterated through to implement a new solution in case of sub-par results obtained in stage five, or new additions for publications in stage six.

C. Model proposition

This section presents a model prototype for the IoT system based on the objectives specified in section A. The system's hardware and software, as well as the general workflow, will be outlined. Fig. 9 shows a prototype of the system's architecture.

For hardware, the system will use a Raspberry Pi with a camera module, and an Arduino board capable of detecting motion. For software, Node-RED will be utilized to establish communication between the Raspberry Pi and Arduino.

When the Arduino detects that the cargo door has been opened, the Raspberry Pi's camera is activated. The camera scans for QR codes, and when identified, it will read the information stored in the QR code and record the loading/unloading of the corresponding cargo. The information obtained through the QR code and video will be saved for further reference.

IV. Conclusion

Concluding the research conducted on this paper, there is a lot of projects that combine IoT with logistics services, however there's still potential for innovation. Majority of studies focus on tracking shipments, and only a handful attempt to detect parcel damage.

Given the room for potential, this paper recognizes existing efforts and provides an early prototype of an IoT system capable of monitoring handling of deliveries.

This system aims to improve courier businesses' rentability, by aiding return disputes and monitoring drivers' handling of goods.

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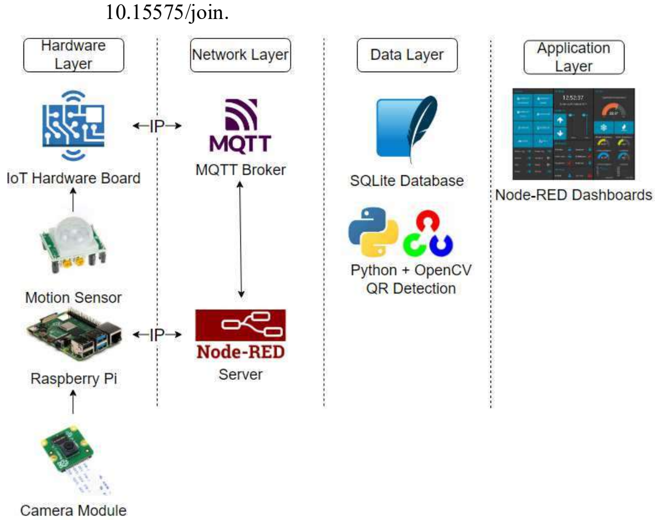

Fig. 9. Proposition for the system's architecture

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