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Posted Date: 12 February 2024

doi: 10.20944/preprints202402.0705.v1

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IoT and Business Intelligence Based Model Design for Liquefied Petroleum Gas (LPG) Distribution Monitoring

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Abstract: Gas leakage can occur for various reasons, including a gas leak in the distribution line, damaged regulators, service connection failures, fluctuations in inlet gas pressure, and other factors leading to millions in losses to the state. The objective is to develop a general and intelligent model for tracking and monitoring LPG distribution based on the Internet of Things and Business Intelligence technology. Devices such as sensors and actuators reduce risks and prevent accidents. IoT can also access automatic control of machines and infrastructure, and sensors' data helps make intelligent decisions. The quantitative approach is used in the systematic review methodology based on the PRISMA statement; the architecture design is based on analytical research that studies the feasibility of a measure through empirical evidence; and the architecture description uses a qualitative approach. The Y.4908 Standard evaluates an IoT network's interoperability, usability, and security. A targeted group of thirty IT professionals was surveyed to assess the Business Intelligence model. Forty scientific papers were selected for analysis. A model with IoT components and a four-level business intelligence system was found. At the overall average level, 49% strongly agree, 38% agree, 12% neither agree nor disagree, and 1% disagree. In other words, the model has an overall average approval rating of 87%.

Keywords: Internet of Things; IoT; LPG; sensing approach; Business Intelligence; Liquefied Petroleum Gas

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1. Introduction

The high demand for liquefied petroleum gas (LPG) and natural gas leads to higher production; therefore, equipment and implements become one of the most essential points to maintain operability. Consequently, it is necessary to improve safety conditions in the company by optimizing the control and detection techniques of all machinery to ensure its proper functioning for the safety of companies and people. The demand for energy such as heating, manufacturing, household appliances, and fuel for vehicles comes mostly from liquefied petroleum gas; in addition, gas replaces gasoline or coal because of its advantages against the environment [1]. On the other hand, gas is lost for different reasons, such as gas leakage during the distribution line, damaged regulators, faulty service connections, and a fluctuation in the inlet gas pressure, among others. The leakage or loss of gas originates dangers to people, economic losses, and an increase of greenhouse gases; LPG distribution has no detection or control of gas leaks; there are only manual reports or complaints from users, this generates vast amounts of carbon emissions into the atmosphere [2].

It is known that GAS detection is essential in different areas such as medicine, industry, environment, and monitoring of sealed spaces; the automotive sector uses gas sensors in engines to minimize contamination and maximize power; in treatment, gas monitoring in hospitals, in subway mines gas monitoring ensures air quality and avoids damage due to lack of oxygen. LPG leakage causes fires, intoxications, and explosions at the moment of combustion; the costs are also linked to the aftermath of gas leaks, such as the destruction of infrastructure, medical expenses, and loss of

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income [3]. LPG is highly flammable and used in the home, vehicles, companies, and other areas; there are varieties of LPG for its propane and butane content; it has an explosive characteristic that is a fire risk in any place or during transportation. Negligence and ignorance cause accidents; some implementations use gas sensors and are outdoor solutions in environmental monitoring, chemical processes, fire detection, and air quality, among others. LPG leak accidents cause loss of human and material lives; it is true that accidents are few but very dangerous; there are houses or citadels with LPG connections, although there are very few such facilities, and there are no tasks after the detection of gas leaks. The subsequent functions are the activities that people must perform after detecting a gas leak; as an instinct of people, a widespread mistake is to turn on the light bulbs that activate the current switches when entering the house or company; the gas that is in the environment can easily catch fire from the spark or short circuit, this is a threat when gas leakage incidents occur. It is common knowledge that gas leakage is a serious problem, regardless of the sector related to gas, such as companies, homes, factories, kitchens, and restaurants, among others [4].

As the use of LPG increases, so does the number of accidents caused by LPG explosions; accidents generated by gas leaks stimulate property damage and fatalities. Some problems are poor quality piping, poorly made pipe joints, inferior quality gas cylinders, worn regulators, obsolete valves, and improper handling of gas cylinders. Other problems are: the leak detection system has certain drawbacks, long response time, lack of prevention mechanisms, and the installation of faulty or untested leak detection devices. [5]. As of 2022, Ecuador's LPG consumption was 14.4 million barrels, of which 12.7 million were imported and 1.7 million were produced locally [6]. At the national level, LPG consumption is distributed as follows: domestic is 91%, industrial is 7%, agricultural is 1%, and automotive is 1% [7]. It is common knowledge that even the slightest LPG leakage can cause severe damage to people, houses, buildings, or businesses; the safety of people is a significant concern. To avoid gas leakage, it is essential to continuously monitor the LPG supply; Internet of Things (IoT) technology can perform sophisticated supply control and monitoring [8].

The use of devices such as sensors and actuators decreases risks and prevents accidents; IoT accesses the automatic control of machines and infrastructures; objects are fed with data that are generated by sensors and yield to intelligent decision making; IoT is part of air conditioning, heating, and ventilation environments that are integrated to gas sensors, windows, alarms, gas valves to minimize domestic and industrial accidents [3]. Technologies are used for gas management in gas metering, gas leakage monitoring, pressure monitoring for gas pipeline networks, and detecting abnormal events [9]. In addition, IoT plays a fundamental and essential role in instrument design because it provides all the details and specifications necessary to protect companies or individuals against accidents that leaks of flammable gases may cause; also, IoT devices, through the use of sensors, can detect, store and process data from the environment, and the use of sensors has advantages such as reliability, ease of use, flexibility, accuracy, and cost-effectiveness [4].

A model for a gas leak detection system avoids leaks and prevents the possibility of fire; post-leak activities are improved so as not to cause an increase in risk. Exploitation due to a gas leak can be avoided and overcome any accidents. It is paramount to maintain safe, reliable, accessible, and modeled gas energy services to minimize risk and promote economic development. If the chance to users can be caused by gas cylinder explosions, transportation, or gas storage, then this risk must decrease as consumption increases nationally.

The objective is To design an intelligent and general model for tracking-monitoring in LPG distribution based on IoT and BI technology. The specific aims are to: a) design a general architecture for the control and monitoring of the distribution, storage, and use of LPG based on IoT and BI technologies; b) evaluate the IoT network and BI model to determine the interoperability, ease of use and security through the Y.4908 Standard and c) conduct and analyze the survey to IT specialists. This paper proposes a model for an intelligent system in the detection, control, and monitoring of LPG by using the Internet of Things (IoT) and Business Intelligence (BI). IoT technology is used to capture gas quantities or gas leakage and to send notifications in a faster way; monitoring is remote, which helps in a system to detect LPG leakage in places like restaurants, homes, or industries, and take early prevention in case of leakage during transportation or use. BI determines the indices (e.g., humidity, temperature, gas level) to monitor and model a data warehouse related to LPG management.

2. Related Work

LPG has been produced since 1914. It is a mixture of hydrocarbon gases used in homes and industries. The gas is toxic, colorless, and odorless. It is a fuel for heating, cooking, and vehicles (Gomes et al., 2019). LPG is available in much of the world to meet domestic requirements and industry needs. It is a mixture of propane and butane, which are very flammable. LPG is heavier than air, and if a person inhales it, then it causes asphyxiation [8]. LPG has ethanol added as a characteristic odor to prevent harmful events and identify leaks at any time or space; it replaces other types of fuel systems in commercial, domestic, and industrial areas; it is an explosive gas containing between 1.8% and 9.5% of the volume of gas and air [4].

It is a network system for connecting things via the Internet based on protocols used in data-sensing equipment; it is an "intelligent emerging technology" that maintains the interconnection between devices with computing capabilities that are interconnected to the Internet. It is a communication paradigm comprising sensing devices, modules, and microcontrollers that pass digitized data [2]. IoT consists of interconnected networks and people sharing data inside or outside the environment found in the home, industry, sports, agriculture, transportation, medicine, and environment [10], and allows establishing communication among all to achieve common goals for the people's interest.

Business intelligence allows optimizing and improving the quality of business decision-making based on data. BI is compared to information compendiums, reporting tools, executive information applications, and corporate consulting because it uses "business intelligence"; the company's information is processed and visualized in a better way with the help of BI tools. Within BI, a Data Warehouse (DW) is used, which is the logical design of the data repository and is independent of the database; this DW allows the integration of multiple computer application environments and assists the processing of information to generate a single base that consolidates data for analysis purposes [11].

In [2] propose to use IoT to detect gas leaks, monitor leakage data, and control those leaks from remote customers with an on-off via mobile applications and the Internet; they use a gas sensor, valve, microcontroller, a database, online update, and relay. In case of gas leakage, the components are activated, and alarms are turned on; the leakage status is sent to the gas supplier's smartphone; the supplier can shut off the gas valve remotely. In other cases, the gas supplies are shut off automatically if the leakage exceeds the threshold. The paper by [10] proposes a device to detect the leakage of butane or LPG; if the sensor value increases, then an alarm, sound, and lights are activated; also, the sensor reading is displayed; the gas smoke is revealed by a pattern which is convenient for detection.

The prototype of [3] is a multi-gas smart sensor to prevent accidents in innovative environments on carbon monoxide or LPG; the sensor is connected to an IoT environment, and it uses the communication standard to interconnect the data with other smart devices and achieve to make the right decisions.

In [4] designed and implemented a prototype gas sensor. If there is a leakage, the sensor sends a signal to the microcontroller. The microcontroller receives and processes the call, and then the relay module shuts off the current supply to avoid sparks or short circuits generated by turning off switches and preventing explosion accidents. The prototype detects changes in LPG concentration at a short distance and displays the amount of particles per million (PPM) as an indicator.

In the research, they developed an electronic system to monitor LPG, natural gas, butane, humidity, temperature, and heat indicators through a web server; if there is a gas leak or if a parameter exceeds its threshold value, then an alarm is triggered, and a text message is sent to the authority. The system has sensors, a controller, a web server, and a display showing the sensor value [8].

In [1], they implemented an automated method to detect gas leaks through sensors connected to an alert and command system; the peripheral is effective, simple, low cost, portable, ultralight, and reliable; this helps in the sanitary sector because when there is a gas leak pollution, and waste is minimized, and increases the economy.

It uses IoT technology that gets faster responses on LPG systems; this IoT passes alerts on gas leaks to avoid accidents; it uses a microcontroller device, a gas detector, the model activates preventive measures by buzzer, has a GSM module, a solenoid valve, a LED light for indication, an air extractor, gas sensor and a humidity-temperature sensor [5]. The IoT-based system of [12] is developed in four phases: data collection, hardware design, program coding, and system testing; this generates a tool to detect LPG leaks. When detecting anomalies, alert messages are sent by telegrams or buzzers; the system categorizes the concentration of LPG into two categories.

The [13] system has a first segment that monitors and a second segment that regulates the smoke and gas output through a controller; if the smoke sensor detects a leak, then a signal is emitted to the controller to turn on the exhaust fan then, it also stops the gas flow through the solenoid valve. The display shows the sensor value and a switch turns on the exhaust fan and the valve.

The article by [9] uses Artificial Intelligence (AI), Blockchain, and IoT technologies for a gas architecture in an intelligent city; AI algorithm uses the prediction model for gas production after detecting the change in gas delivery capacity; Blockchain is used to establish a secure transaction scheme, and maintain the buy-sell contract; simulations show the prediction on gas production in real-time and selection of dynamic sales transactional plan. The research of [14] explores BI in the domain of industries in gas refining through the identification and classification of deployment factors in Iran.

3. Methodology

The methodology explains the details of achieving and developing the specific objectives in this article.

Analyze scientific articles to learn about other IoT and BI models through a systematic literature review. The systematic review attached to the PRISMA statement of [15] is used, which has three phases, see Figure 1:

1. Identification of studies: it is based on a search in one or several library databases; IEEE, ACM Digital Library, and Web of Science are considered; peer-reviewed articles are used. Mendeley software is used to eliminate duplicate articles. The filtering keywords are IoT, Business Intelligence, and LPG.;
2. Eligibility criteria: It is necessary to define the types of studies that could be considered for this study. The inclusion criteria for eligibility are as follows: The article is scientific. It is Written in English. The Content is on IoT or Business Intelligence in LPG management. The exclusion criteria are as follows: The article is younger than 2018. It is in a language other than English. It is an Abstract article. It is a Paid article.

   The following research questions (PI) are defined:

   - PI1: In which scenarios is IoT used (e.g., industry, household, housing estates, distribution, supplier)?
   - PI2: What devices are used in LPG monitoring (e.g., sensors, microcontrollers, buzzers)?
   - PI3: What other components are used (e.g., server, web application, mobile application)?
   - PI4: Are other technologies used for LPG monitoring (e.g., Blockchain, AI, Big Data)?
   - PI5: What is monitored (e.g., gas leakage, transport, pipelines)?
   - PI6: What is the result of the research (e.g., design, implementation)?
   - PI7: What gases are monitored (e.g., LPG, natural gas, butane, carbon monoxide, nitrogen dioxide, sulfur dioxide)?
   - PI8: What data are detected (e.g., humidity, temperature, heat indicator)?
   - PI9: What protocols are used (e.g. IEEE, 6LoWPAN, MQTT)?
   - PI10: What indicators are displayed (e.g., humidity, temperature, gas level)?

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- PI11: What software tools are used in Business Intelligence?
- PI12: What general data do the data warehouses have?

3. Data collection and synthesis: Data covering the identified articles are extracted, the research questions are answered, and data analysis is performed in quantitative form and described for explanation. The study uses a quantitative approach.

Figure 1. Systematic review.

Based on IoT and BI technologies, design an overall architecture for LPG distribution, storage, and use, including control and monitoring. The architecture covers LPG plant storage, pipeline or transport distribution, and use in homes or businesses. The architecture design is based on analytical research that studies the feasibility of a measure through empirical evidence. The qualitative approach describes all the architecture details, such as participants, components, software, hardware, networks, and indicators. The architecture graph is presented.

The Y. 4908 and a survey of IT specialists are used to evaluate the IoT network and BI model for interoperability, usability, and security. Standard Y.4908 [16] evaluates the IoT network's interoperability, usability, and security; see Table 1.

Table 1. Evaluation factors.

		Capacity	Yes	No
Network Interoperability		Interconnected		
	Device List			
	Systems List			
Data Interoperability		Interconnect		
	Device List			
	Systems List			
Service Interoperability		Integrate		
	Device List			
	Systems List			

Source: Authors.

The survey technique is used with a specific group of at least 30 professionals in Information Technology, Information Systems, or Computer Science. Some of the questions are: a) The BI model presents the origins of the data, b) The Data Warehouse model is presented, c) The ETL is presented, d) The names of the indicators are presented, and e) The names of the reports are presented. f) The software named is appropriate. g) The DW contains dimensions and facts.

4. Results

4.1. Analysis of scientific articles using a systematic review of the literature.

The articles selected through the PRISMA methodology are considered. Figure 2 presents the flowchart on the themes identified, reviewed, and set. After the initial search in IEEE, ACM Digital Library, and Web of Science library databases with the keywords "IoT" or "Business Intelligence," 148 articles were identified. After eliminating duplicates, illegible, and removed for other reasons, these were reduced to 113 pieces. A further 11 articles were excluded due to their title and abstract needing

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to fall into the eligibility criteria; this led to 102 articles being sought for retrieval. The articles were then reviewed for IoT and Business Intelligence descriptions or models. Exclusion criteria are applied sequentially according to age, article type, or payment; otherwise, the evaluation is continued. Other exclusion items are articles that mention the term IoT or BI but do not apply it; articles that mention IoT or BI in general and not as results; articles that do not demonstrate the influence of IoT or BI; and articles that are only concepts in total are 35. In the end, 40 papers were selected for analysis, as shown in Figure 2; all these articles are in the Reference section, and the complete list of articles is in Table 2.

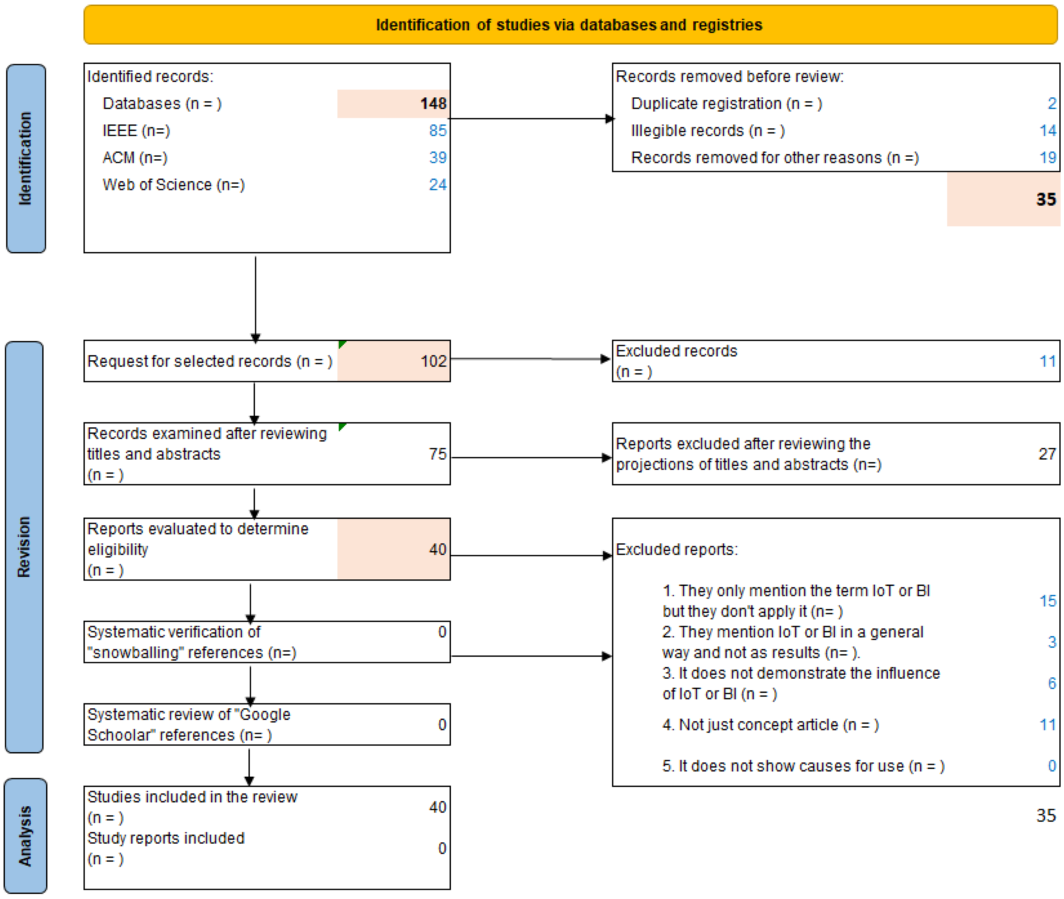

Figure 2. Prisma.

Peer-reviewed articles published in English between 2019 and 2020 were considered. This increased academic interest in the area could be attributed to the growing number of urban platforms worldwide. As part of the eligibility criteria, each article described at least one urban crowdsourcing platform, but some described or mentioned more than one platform.

Among the 40 selected articles, only 23 present models or architectures on IoT or Business Intelligence applied in LPG control; others present technology or alternatives for gas tank control. Each of the 40 articles is reviewed if it contains a property that falls into the following groups: IoT scenarios, Monitoring devices, Other components, Other technologies, Control, Research results, Gases they monitor, Data they detect, Protocols used, Indicators they show, Business Intelligence software, Data from Data Warehouse.

Each of the items is reviewed and the properties of each item are: Item, Year of production, Item title, Country of origin, and number of references. In addition, the IoT Scenarios segment with properties: Industry, Home, Distribution, Supplier. The Monitoring devices segment with properties: Sensors, Microcontrollers, Buzzer, Valve, Relay, Fan, Display, LED. The segment Other components with properties: Server, Web application, Mobile application, Database, GSM, GPS. The segment

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Other technologies with properties: Blockchain, Artificial Intelligence, Business Intelligence. The Control segment with properties: Gas Leakage, Transportation, Pipelines, Weight. The Research Result segment with properties: Design, Implementation, Prototype. The segment Gases Monitoring with properties: LPG, Natural Gas, Butane, Carbon Monoxide, Nitrogen Dioxide, Alcohol, Oxygen, Propane, Hydrogen, Methane. The segment Data they detect with properties: Humidity, Temperature, Smoke, Fire, Gas. The segment Protocols used with properties: IEEE, 6LoWPAN, MQTT, TCP. The segment Indicators showing with properties: Humidity, Temperature, Gas level, Smoke, Heat, Cylinder status. The segment Business Intelligence Software with properties BLYNK, Excel, PowerBI. The Data Warehouse Data segment with properties Weight, Voltage, Level. Table 1 shows the 40 items analyzed and used to answer the research questions (PI).

Table 2. Classified and selected papers.

Year	Papers	No
2019	[3,14,17–23]	9
2020	[8,24–27]	5
2021	[2,4,9,10,12,13,28–33]	12
2022	[34–38]	5
2023	[1,5,39–45]	9

Source: Carried out by authors.

4.2. *Answer to the research questions.*

PI01: In which scenarios is IoT used?
According to the analysis of the 40 papers, 58% of the proposals are for industry, 45% are for homes, 5% are for management in gas distribution, and 8% are suggestions for gas suppliers. Conversely, 12% specify industry and household, i.e., five things. See Figure 3 Scenarios.

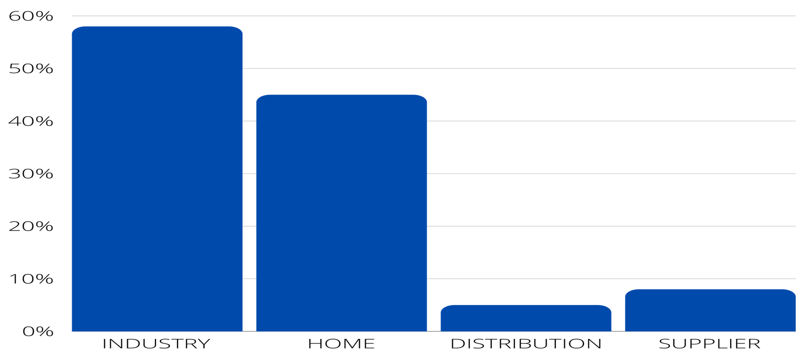

Figure 3. Scenarios.

PI02: What devices are used in LPG monitoring?
According to the analysis of the 40 papers, 88% use sensors, 83% use microcontroller cards, 48% use buzzers to alert, 55% use valves to close the tank, 55% of the documents use a relay to activate the valves; 23% of the items use a fan to dissipate the gas; 55% use a display to show the status or quantity; 40% use a LED light to alert of gas leakage. On the other hand, 83% use sensors and microcontrollers, i.e., 33 items. Another 33% use LED with relay and valve as prevention and warning, i.e., 13 papers. In addition, 48% that use buzzers to alert are among the 83% that use microcontrollers and sensors, i.e., 19 items. The buzzer, fan, and LED are linked to the microcontroller. See Figure 4 Devices.

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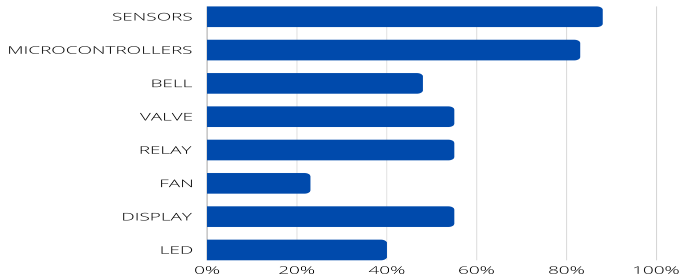

Figure 4. Devices.

PI03: What other components are used?

According to the analysis of the 40 papers, 48% use or have an application server, 30% have a web application, 58% use a mobile application, 33% use a database, 40% use GSM to send text messages, 8% use GPS for gas leak positioning. The tendency to use mobile applications remains high, as does using GSM to send simple text messages because they are very efficient for communication. GPS communication is rarely used because of the monthly costs providers charge for this service. On the other hand, databases are used by web applications or mobile applications; GSM modules may or may not be integrated into the microcontroller card. Web applications are linked to a server. See Figure 5 Other components.

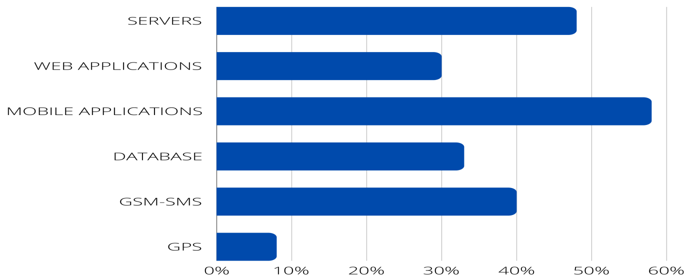

Figure 5. Other components.

PI04: Are other technologies used for LPG monitoring?

According to the analysis of the 40 papers, 3% use Blockchain to maintain information security in encrypted form and maintain traceability/tracking in gas distribution; 8% use Artificial Intelligence for possible predictions in gas leakage; 13% use Business Intelligence to generate reporting or control indicators. On the other hand, the same article that proposes to use Blockchain also uses Artificial Intelligence. There is no overlap in using Business Intelligence with other technologies. See Figure 6 Other technologies.

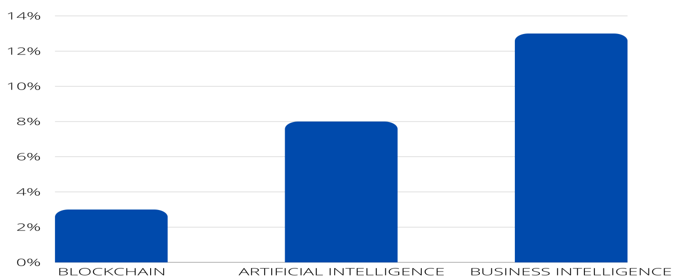

Figure 6. Other Technologies.

PI05: What is controlled?

According to the analysis of the 40 papers, 73% propose controlling gas leakage, 3% offer governing gas transportation, 15% propose controlling gas pipelines, and 15% suggest controlling LPG tank weight. However, only some of the articles submit gas leakage control. The papers that work on Business Intelligence only obtain data from files generated by sensors, and others are only theoretical articles. On the other hand, 13% of control pipelines are within the 73% gas leakage control, i.e., five pieces. In addition, only one paper proposes a rule during the gas transport process. See Figure 7 Control.

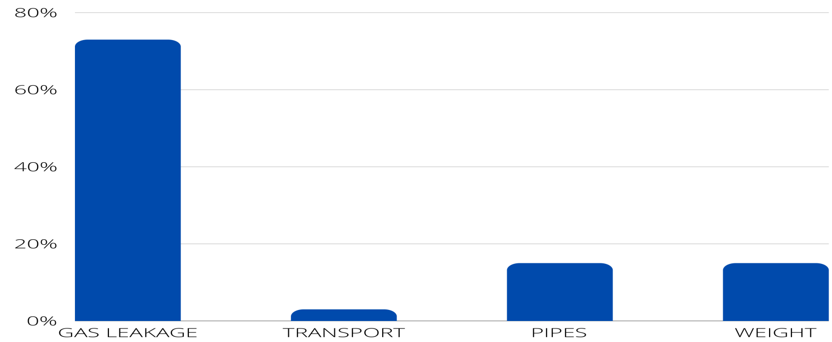

Figure 7. Control.

PI06: Research results?
According to the analysis of the 40 papers, 83% present as a result of the network design or device design; 23% performed the implementation and use of their plans; 58% achieved a prototype to demonstrate their theories on device design in gas leakage control or LPG cylinder weight. On the other hand, two papers should have presented the method and implementation. The rest of the articles that were designed were also implemented. All the documents with prototypes did give their design, and all the prototypes presented photos of their work. See Figure 8 Results.

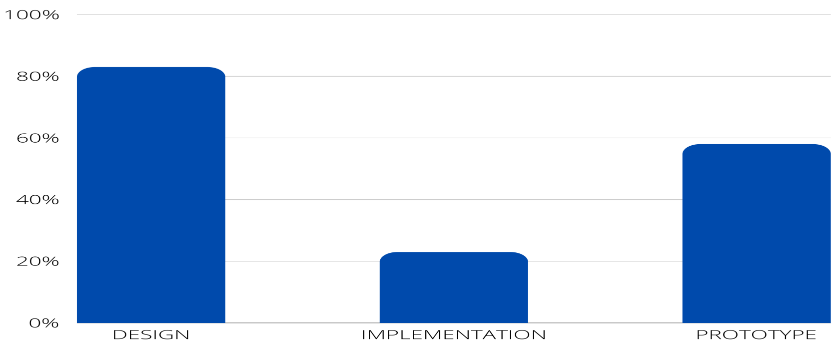

Figure 8. Results.

PI07: What gases are monitored?
According to the analysis of the 40 papers, 85% monitor LPG from home or industry, 18% monitor Natural Gas, 25% monitor Butane, 20% monitor Carbon Monoxide, 10% monitor Nitrogen Dioxide, 10% monitor Alcohol, 10% monitor Oxygen; 18% monitor Propane; 23% monitor Hydrogen; 23% monitor Methane. On the other hand, 8% of natural gas monitoring is within LPG monitoring, i.e., three items. The other four items only monitor Natural Gas. All the articles monitoring Butane are within LPG monitoring, i.e., ten articles. The 18% that watch Carbon Monoxide is within the LPG monitoring, i.e., seven items. Items monitoring Nitrogen Dioxide, Alcohol, and Oxygen are within LPG monitoring, i.e., four items each. The things that observe Propane, Hydrogen, and Methane are within LPG monitoring. This happens because there are sensors that can detect few or many gases; the sensors used in the items are MQ2, MQ3, MQ4, MQ5, and MQ6. If the number is higher, then more gases can be detected. See Figure 9.

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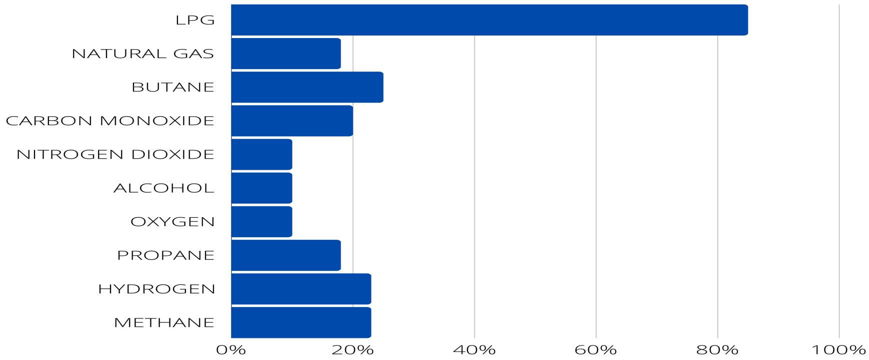

Figure 9. Gases.

PI08: What data is detected?
According to the analysis of the 40 papers, 15% present designs that detect humidity, and 15% detect temperature; 10% of the designs detect smoke; 8% of the methods detect fire; 88% of the designs detect gas, either by gas leakage in cylinder or pipe leakage. On the other hand, the techniques that detect humidity and temperature are among the 88% that detect gas. The designs that detect smoke or fire are within 88% that detect gas. See Figure 10. Data detected.

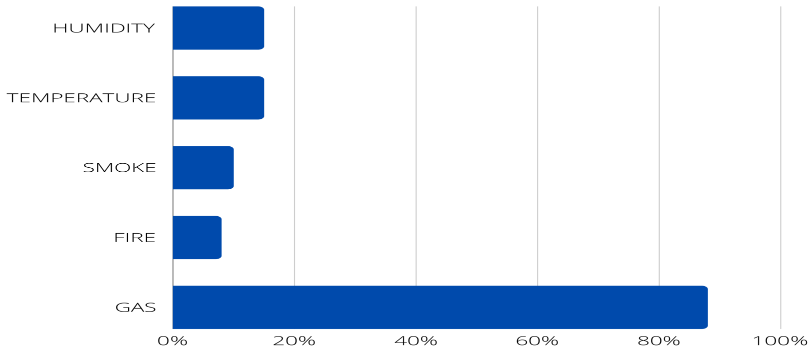

Figure 10. Data Detected.

PI09: What protocols are used?
According to the analysis of the 40 papers, 43% name or use the IEEE protocol in their implementations or prototypes; 5% name or use the 6LowPan protocol in their designs; 8% name or use the MQTT protocol in their designs; 25% name or use the TCP protocol. On the other hand, 10% of the articles used any of these protocols in implementation, i.e., four papers. 38% of the documents used protocols in prototypes, i.e., 15 pieces. The 25% of the TCP articles are within the 43% using IEEE. See Figure 11 Protocols.

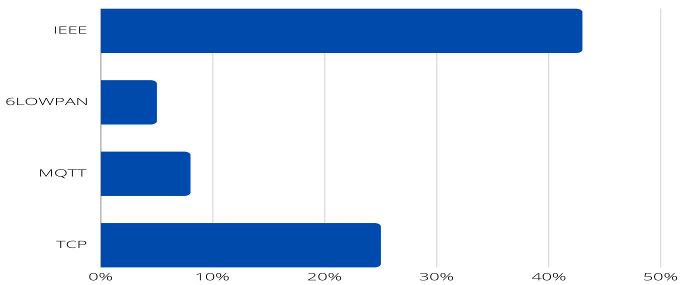

Figure 11. Protocols.

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PI10: What indicators are shown?
According to the analysis of the 40 papers, 13% show the humidity, 10% indicate the temperature, 73% offer the gas level, 8% show the smoke level, 3% show the heat level, and 25% show the bottle status. On the other hand, humidity, temperature, and gas levels are shown on the display in 10% of the items, i.e., in 4 pieces. In 8% of the items, i.e., three things, gas, and smoke levels are displayed on the screen. Only one report shows humidity, temperature, gas level, smoke, and heat as indicators. Only one article shows humidity, temperature, gas level, and smoke as indicators. Only one item presents humidity, temperature, and gas level as indicators. See Figure 12 Indicators.

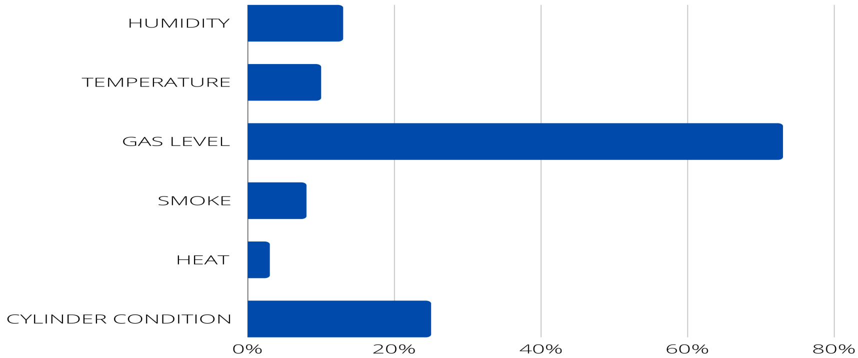

Figure 12. Indicators.

PI11: What software tools are used in Business Intelligence?
According to the analysis of the 40 papers, 15% of the 40 articles use Blynk, 5% use Microsoft Excel, and 5% use Microsoft Power BI. On the other hand, only one piece uses Excel and Power BI; the other articles use these tools independently. See Figure 13 BI software. Blynk is used to connect IoT devices, assist in the visualization of sensor data, execute remote control with mobile web applications, perform firmware updates, and offer a secure cloud, user and access management, and alerts, among others. In addition, this platform promotes smart home hardware manufacturers [46]. Microsoft Power BI generates simple data sets with many data sources or origins, is also simple for aggregation to the Power-BI data connectivity hub, and generates a centralized, single, effective, and accessible source of information for data from multiple devices [47].

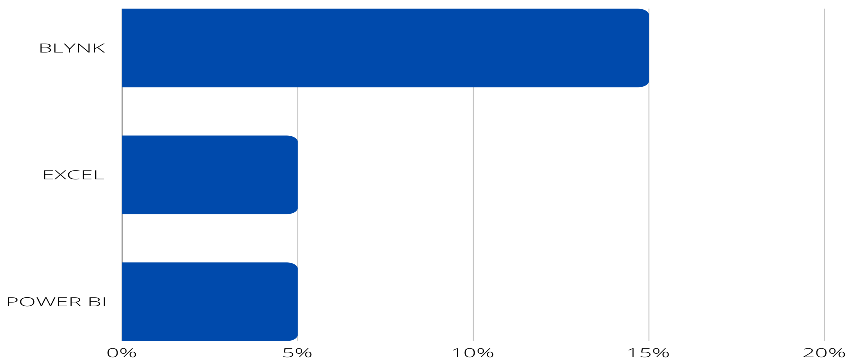

Figure 13. Software BI.

PI12: What general data does the Data Warehouse have? According to the analysis of the 40 papers, 8% show the weight in the DW, 8% show the voltage in the DW, and 10% indicate the gas level in the DW. On the other hand, 8% of the articles present the weight and voltage together, i.e., in 3 pieces. The 10% of the items showing the gas level do not have any DW data in common with the other 8%. See Figure 14 for the DW data.

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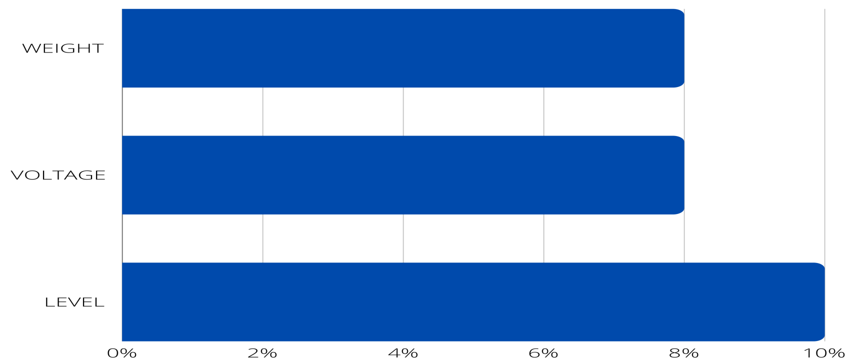

Figure 14. Data in DW.

4.3. Design of a general architecture for LPG management based on IoT and BI.

In the event of a gas leak, the Gas Sensor detects the strength of the leak and sends the data to the microcontroller. This microcontroller takes that data takes it and sends it to a Firebase database in real-time via the Wi-Fi router and the Internet. The Firebase database sends the data to the smartphone via the Internet. In addition, GSM communication can be added to send text messages and an audible alarm on-site. The leak volume is displayed on the LCD screen and the smartphone. There is a predefined threshold of 500 PPM; if the leak volume is less than 500 PPM, the relay and solenoid valve are turned on, letting the gas pass through the pipeline. If the leak volume is more significant than 500 PPM or if pressing the RED toggle button on the smartphone, then a control signal is sent from the smartphone to the microcontroller via the Firebase database; this action turns off the relay and solenoid valve to not let gas pass through the pipeline.

Components:

1. MQ-5 gas sensor. Detects LPG and natural gas with excellent accuracy. Obtains the presence of gas with a concentration from 2000 PPM (Parts Per Million) up to 10000 PPM and operates with 5 volts of power.
2. MQ-6 gas sensor. It detects the presence of LPG. It is an analog sensor based on resistance. It obtains the presence of gas with a concentration from 200 PPM to 10000 PPM.
3. Temperature and humidity sensor. The DHT11 digital sensor is a low-cost sensor that measures air temperature and humidity. It can measure temperature from 0 to 500 °C with an accuracy of ±2 °C and humidity from 20 to 80% with an accuracy of 5%. It consumes power from 3 to 5 volts and draws a current of up to 2.5 milliamps while reading data.
4. LCD. The 16cm x 2cm liquid crystal display is connected to the NodeMCU via I2C communication protocol. The LCDs the data obtained by the sensors, such as humidity, temperature, and gas status, in real-time on-site.
5. NodeMCU DEVKIT 1.0. NodeMCU is open-source firmware for the IoT platform. This hardware is a microcontroller unit with a wifi chip. It is an excellent low-cost option for sending data to a web server, LCD, GSM, and relay. This control unit takes the data obtained by the sensors. After analyzing the sensor data, this microcontroller executes the appropriate actions.
6. Audible alarm. The buzzer is added to notice nearby people. If the sensor detects the presence of gas in the air, then the NodeMCU activates the audible alarm.
7. GSM modem (SIM800L). This hardware connects to the NodeMCU to send and receive text messages (SMS). The modem has a SIM card and must be with a subscription to a mobile operator. If the sensor detects the presence of gas or out-of-range value, then the microcontroller sends an automatic notification to a cell phone number about the gas leak. In addition, it is possible to query the status of the gas leak by SMS remotely.
8. Relay. It is a device that operates the solenoid valve.

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9. Solenoid valve: This device controls gas leakage; it turns on or off through the relay module according to the signal from the microcontroller.
10. Wifi router. It is a wifi router device for Internet connection.
11. Smartphone: This is a control unit. It can access mobile applications on the solenoid valve and remotely turn it on or off.
12. Google Firebase is a platform for storing and processing leakage data. This database sends the data from the microcontroller to the mobile applications in real time.
13. Arduino IDE and C++ programming. The microcontrollers are programmed in Arduino IDE and C++ programming language.

MQ-5 and MQ-6 gas sensors are good choices for detecting flammable gases and LPG and their proportion in the air. Measuring temperature and humidity is significant to know the heat index. With these sensors, the NodeMCU microcontroller can explore the possibility of accidents. After the sensors detect leakage and measure the leakage volume in the PPM unit, they send the data to the microcontroller. The microcontroller verifies the data, according to the parameters, in this case, if the leakage value is greater than 500 PPM, then the solenoid valve is shut down automatically. See Figure 15.

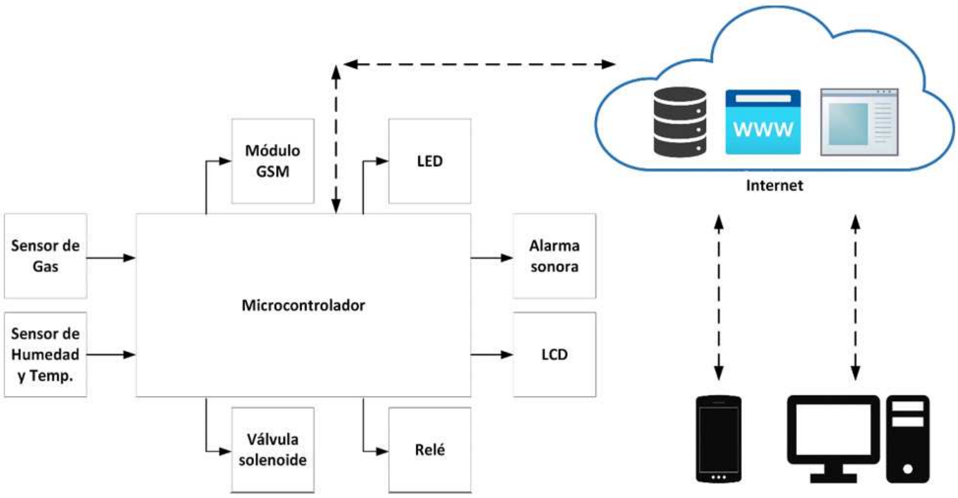

Figure 15. IoT device at control points.

The web application presents the important index values (gas percentage, heat index, humidity, smoke presence, and temperature). In the web application, you can understand the gas leakage situation or the normal state, and it is unnecessary to understand the sensor values. If there is a gas leak, an alarm is generated on-site, and an SMS text message is sent to minimize the possibility of an accident. The GSM module allows a message to be sent for the presence of gas or other out-of-range sensor values, and it is possible to query the current sensor values. The smartphone receives the data from the server via the mobile application. In addition, the on/off interface is displayed. If the leak volume exceeds 500 PPM, you must press the shutdown button (RED) on the smartphone to control the gas leak. The command data is transmitted to the microcontroller via the Internet database. The solenoid valve can be opened via the GREEN button on the smartphone. See Figure 16.

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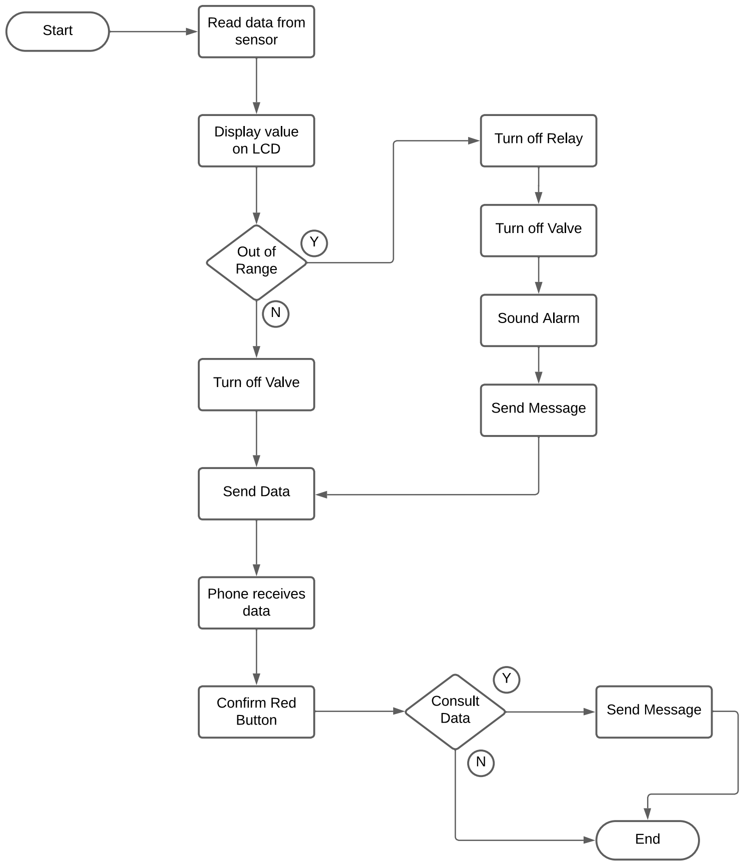

Figure 16. IoT Flow.

The Business Intelligence part [48] takes the source data from the database in the cloud; in this database are the measurements of all the sensors in the LPG distribution network, i.e., humidity, temperature, and particles per million in each fraction of time. Other data that exist are transport, time, and quantity. It is recommended to use Microsoft Power BI Desktop (PowerBI, 2023) because it is very intuitive.

The BI model has four levels; Figure 17 represents the model based on IoT and BI.

1. Data Source: This is the Firebase in the cloud. The database contains the Sensors table with column identification, series, sensor name, location, start date, and status. The Measurements table has columns such as sensor, humidity level, temperature level, PPM level, date, and time.
2. ETL: There is the ETL process (Extraction-Transformation-Load); here, the Power BI tool performs the validation, cleaning, transformation, and aggregation of the data and then performs the load to the Data Mart. In this case, the source data belongs to a single database; the data is homogeneous in the extraction; the extraction is performed every hour or according to the Power BI configuration; in the data cleansing, unnecessary data is discarded. Data is considered valid because it is in a database; data such as sensor series and start date are discarded in data cleaning. The cleaned data is loaded into the Data Warehouse, and the data belonging to the Facts table is loaded into the Power BI tool.
3. Storage: There is the datamart, the data warehouse, and the cube; remember that the source database comprises two-dimensional tables or straightforward data. The Power BI tool obtains this multidimensional data on the sensors. A multifaceted analysis allows thinking, reducing confusion, avoiding lousy perspectives, and seeing from another angle and other facets.
4. Visualization: This BI results in view contains dashboard sorts; the previous steps could be performed in the Power-BIPower BI.

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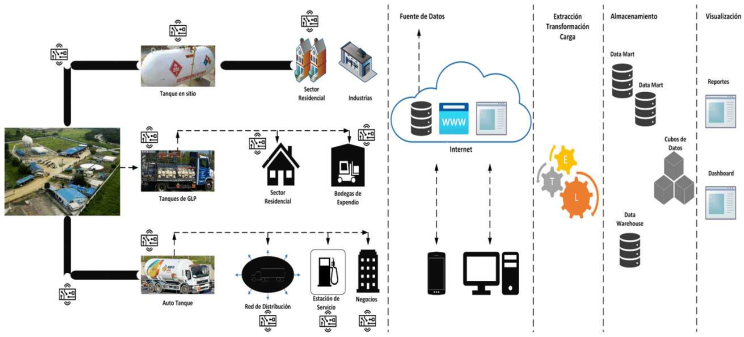

Figure 17. IoT and BI based model.

The Data Warehouse gets the data from the IoT network; from this IoT, it receives the humidity, temperature, and PPM data, which are stored in the database in the cloud. In the database are other data such as city names, province names, sensors names, microcontrollers lists, gas supplies lists, threshold parameters by gas type, daily sensor activities, customer list supply lists, and customer services lists. The lists become the dimensions of the DW; the facts are the technical and daily indicators. The technical indicators help to track the LPG dispatch. The daily hands keep the history of the sensors to perform averaging and presentation of carvings on the dashboard.

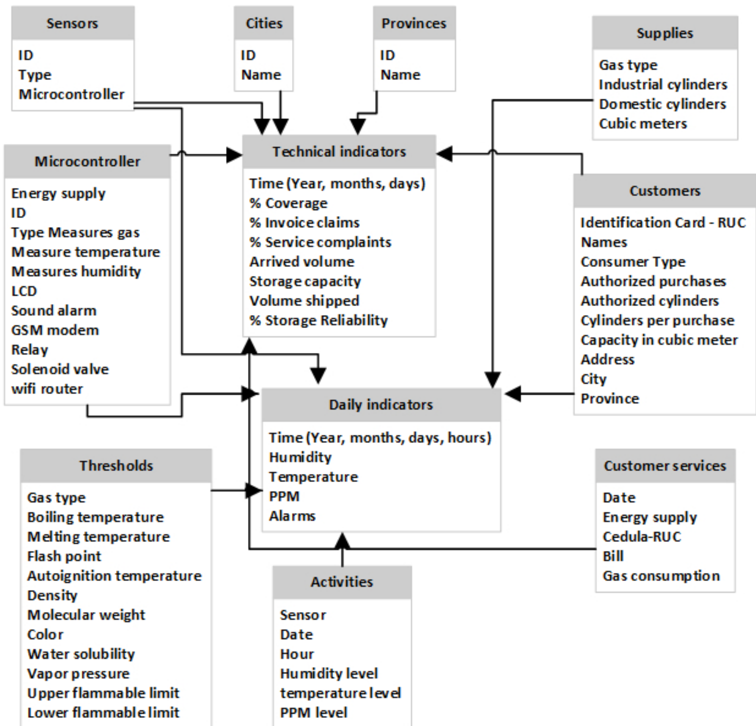

Figure 18. Facts and dimensions.

The reports that the dashboard can present are a list of alarms by city, a list of thresholds, a list of technical indicators, a list of active microcontrollers, and a list of sensors. It is recommended to use Microsoft Power-BI for the implementation, and the information can be exported to a spreadsheet.

4.4. Evaluate the IoT network and BI model using the Y.4908 Standard and the IT specialist survey.

Standard Y.4908 (ITU-T, 2020) is used to evaluate the IoT network's interoperability, usability, and security; this task was performed by three professionals who participated in the same survey. All three agreed on the answers in the table of evaluation factors about the IoT network. They answered Yes on: List of Network interoperability devices, List of Network interoperability systems, List of Data interoperability devices, List of Data interoperability systems, and List of Services interoperability devices. They answered No on the Service Interoperability Systems List. Dividing 100% for six answers gives 16.66% for each answer. The three professionals answered five questions in the affirmative, i.e., a percentage of 83.33% was obtained. This means the IoT network has an outstanding approval because it exceeds 80%. See Table 3.

Table 3. Evaluation factors.

		Capacity	Yes	No
Network Interoperability		Interconnected		
	Device List		X	
	Systems List		X	
Data Interoperability		Interconnect		
	Device List		X	
	Systems List		X	
Service Interoperability		Integrate		
	Device List		X	
	Systems List			X

Source: Authors.

The survey was administered to 30 Information Technology, Systems, or Computer Science professionals. Ten questions with Likert scale responses were asked for the study, which is "1. Strongly agree", "2. Agree", "3. Neither agree nor disagree", "4. Disagree" and "5. Strongly disagree", used in [49].

Table 4. Results of the survey to professionals.

No	Questions	1	2	3	4	5
1	A BI model presents data sources	44	43	10	3	0
2	The Data Warehouse model is presented	33	47	20	0	0
3	ETL is presented	37	33	30	0	0
4	The names of the indicators are presented	53	40	7	0	0
5	The terms of the reports are presented	57	37	6	0	0
6	The named software is appropriate	34	33	13	0	0
7	The DW contains dimensions and facts	47	40	13	0	0
8	The hands are suitable for this case	57	37	3	3	0
9	The model promotes a culture of data-driven decision-making	57	30	7	3	3
10	The model is clear and specific	57	37	6	0	0
	Overall average	50	38	12	1	0

Source: Authors.

If the percentages of "1. Strongly agree" and "2. Agree" are added together, it is assumed that both groups of people agree on the answer. Survey analysis: In question 1, 87% of the professionals agree that the model presents the data origins of IoT sensors, and 13% disagree. In question 2, 80% of the professionals agree that the article presents the DW model, and 20% disagree. In question 3, 70% of the professionals agree that the model does give the ETL, and 30% disagree. In question 4, 93% of the professionals agree that the research does present the indicators, and 7% have no opinion. In question 5, 94% of the professionals agree that the study shows only the reports' names and 7% do not know. In question 6, 87% of the professionals agree that using Microsoft Power-BI is appropriate, and 13% do not agree. In question 7, 87% of the professionals agree on the dimensions and facts presented in the model, and 13% do not agree. In question 8, 94% of the professionals agree that the indicators presented or named are appropriate, and 6% do not agree. In question 9, 80% of the professionals agree that the model promotes decision-making, and 20% do not agree. In question 10, 94% of the professionals agree that the model presented is transparent, and 6% do not agree. At the overall average level, 49% completely agree with the answers, 38% agree, 12% neither agree nor disagree, and 1% disagree. In other words, the model has an overall average approval rating of 87%.

5. Discussion

The model was designed to detect LPG leaks and automatically shut off the supply to prevent any accidents; of course, the model's capabilities can be enhanced, and IoT devices can be integrated to detect gas leaks. The model simplifies LPG monitoring and detection using IoT. This research presents an alternative to minimize the problem of LPG leaks. The model is intended to notify people about gas leaks in various ways, such as audible alarms on site, SMS text messages, updated web applications and historical data, and mobile applications. Observation and management can be done remotely and effectively. IoT devices can be controlled via web server or cell phone. Although no financial costs are presented, the prices of IoT devices are low and effective in gas leakage monitoring, which can prevent LPG leakage accidents.

The model's possible implementation would help authorities monitor the degrees of gas leakage in essential places, send immediate warnings to the public, and avoid accidents. The gas sensors recognize gases, fuels, and oxygen consumption, making it possible to take quick measures to manage a gas spill. Effective implementation is possible; the target region can be near or far from the base station, and less skilled people can perform verification activities. Based on the performance of this research, components from scientific articles were adopted, and it is inferred that detecting LPG leakage in the design is remarkable. It is helpful in distribution for industry, business, and households, preventing accidents and saving lives. Among the 40 articles selected and analyzed, 58% of the articles are used in industry scenarios; 88% of the pieces use sensors; 58% of the articles use a mobile application; 13% of the articles use Business Intelligence to generate reporting or control indicators; 73% of the articles propose gas leak monitoring; 83% of the themes present network design or device design as results; 85% of the articles monitor LPG from home or industry; 88% of the methods detect gas, either by gas leakage in cylinder or pipe leakage; 43% of the articles name or use IEEE protocol in their implementations or prototypes; 73% of the articles show the indicator on gas level; 15% of the 40 articles use Blynk software for Business Intelligence.

6. Conclusions

The proposed intelligent model provides information on gas leaks and their environment in real-time; the automation of facilities on intelligent control in gas distribution is human and social security for a gas supplier company. Gas leakage problems can be solved in less time. It can minimize carbon emissions into the atmosphere, and promising energy savings can be obtained in gas distribution monitoring. It is possible to achieve the sustainable development goals for Ecuador.

Companies continually seek to improve their competencies and increase customer benefits; business processes can be maintained in other ways, such as tracking product distribution to enhance the quality of service. Using BI technology simplifies and accelerates data integration for the enterprise, and the enterprise dashboard helps track and visualize data. Data is obtained from IoT sensors that are the first to warn of potential LPG leaks. The model combines remote monitoring via a web page, mobile app, or remote alerting from IoT sensors, tracking LPG distribution via a web server and cell phone. The model can trigger an alarm and shut off the LPG passage; no IoT device prices are presented, but the named components are low-cost.

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