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DIGITAL TRANSFORMATION IN THE LPG INDUSTRY: LEVERAGING IOT AND DATA ANALYTICS FOR OPERATIONAL EFFICIENCY

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ABSTRACT

This study presents a comprehensive systematic review exploring the transformative impact of Internet of Things (IoT), Supervisory Control and Data Acquisition (SCADA) systems, and automation technologies on the operational efficiency of the Liquefied Petroleum Gas (LPG) industry. Leveraging the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a rigorous review process was conducted to identify, screen, and synthesize existing research. A total of 90 high-quality articles were systematically reviewed to assess how digital technologies are revolutionizing key aspects of LPG operations, including inventory management, predictive maintenance, and fleet optimization. The findings reveal that integrating IoT and SCADA systems enhances real-time monitoring, significantly reduces manual errors, and improves accuracy in inventory tracking, leading to cost reductions of up to 30%. Moreover, predictive maintenance enabled by IoT data analytics was shown to decrease unplanned downtime by 40% and maintenance costs by 25%, further ensuring the reliability of equipment in this high-stakes industry. The review also highlights how automation and digitalization streamline logistics, optimize fuel usage, and improve customer satisfaction by reducing delivery lead times by 20%. Additionally, these technologies support sustainability goals by minimizing carbon emissions through optimized fleet management. By providing a detailed synthesis of current research, this review not only underscores the benefits of digital transformation in the LPG industry but also identifies gaps in the literature, suggesting avenues for future studies to enhance operational excellence, safety, and sustainability in this critical sector.

KEYWORDS

Digital Transformation; LPG Industry; IoT (Internet of Things); Data Analytics; Operational Efficiency

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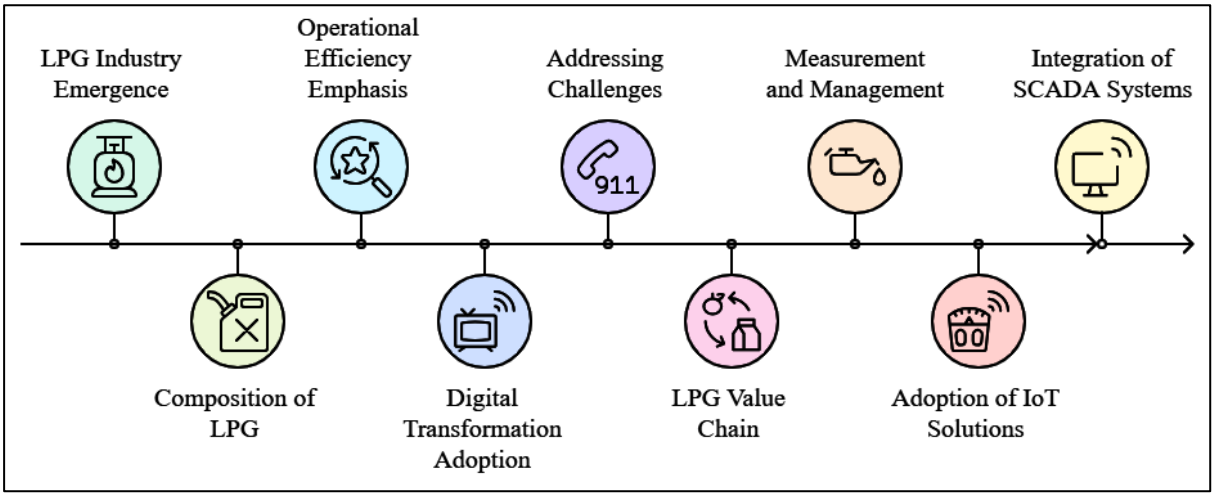
1 Introduction

The Liquified Petroleum Gas (LPG) industry has emerged as a crucial player in the global energy market due to its relatively low carbon emissions and high energy efficiency compared to traditional fossil fuels (Cahyaningrum & Simatupang, 2013). As a green fuel, LPG is composed mainly of propane and butane, which are mixed in varying ratios depending on application and geographical factors to achieve the desired calorific value (Asamoah et al., 2012). In recent years, there has been a growing emphasis on optimizing operational efficiency within the LPG sector to meet increasing demand while maintaining sustainability (Ozoh et al., 2018). Digital transformation, leveraging technologies like the Internet of Things (IoT) and data analytics, has become a pivotal strategy in driving efficiency and minimizing environmental impact in this industry (Agarwal et al., 2021). This transformation addresses challenges such as inventory management, quality assurance, and safety compliance, which are critical to the sector's profitability and sustainability (Lucon et al., 2004). The LPG value chain involves several complex processes, from the extraction of raw materials to the distribution of the final product to end-users. One of the most critical aspects of this chain is the accurate measurement and management of LPG quantities during transportation and storage, as the volume of LPG can fluctuate due to changes in temperature and pressure. Conventional practices, such as manual servo gauge systems and sounding techniques, are prone to human error, leading to discrepancies that can disrupt supply chain efficiency. Advanced IoT solutions, including mass flow meters and real-time data acquisition systems, are being adopted to mitigate these inefficiencies and improve precision in volume measurements (Roy et al., 2010). For instance, the integration of Supervisory Control and Data Acquisition (SCADA) systems with modern measurement devices has enabled centralized monitoring, reducing manual interventions and enhancing accuracy.

As part of the digital transformation, IoT-enabled technologies have significantly optimized the filling and distribution processes in LPG storage and bottling plants (Thoday et al., 2018). Automated filling machines equipped with mass flow meters ensure precise filling by accounting for fluctuations in temperature and pressure, which traditionally caused inconsistencies in fill levels (Zinnuraain et al., 2019). Such automation not only reduces waste but also enhances safety by preventing overfilling and minimizing human intervention. Additionally, digital systems, such as load cells and temperature-compensated weighing mechanisms, have further improved the accuracy of cylinder filling operations. These advancements are crucial for meeting regulatory compliance and maintaining customer satisfaction by ensuring that end-users receive the correct quantity of LPG. Moreover, IoT and data analytics have

Figure 1: Digital Transformation in the LPG Industry



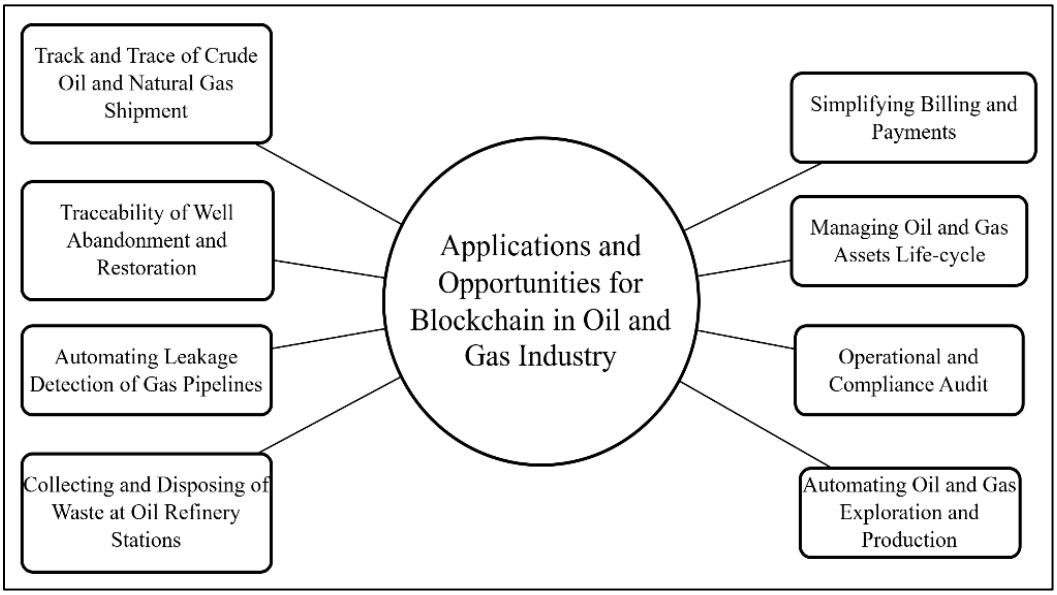
revolutionized logistics and supply chain management in the LPG industry. Technologies such as RFID tagging and GPS-enabled vehicle tracking systems provide real-time visibility into cylinder movement and bulk LPG deliveries, reducing delays and preventing discrepancies (Nautiyal, 2013). By integrating IoT sensors into road tankers and transport vessels, companies can optimize route planning and enhance the accuracy of LPG deliveries (Mittal et al., 2018). These innovations allow for predictive maintenance, reducing downtime and operational costs while ensuring that critical equipment remains in optimal condition. Consequently, the adoption of IoT-driven solutions has enabled the LPG industry to achieve operational excellence, reduce costs, and enhance service delivery (Nautiyal, 2013).

The role of digital transformation extends beyond operational efficiency to include compliance with increasingly stringent environmental and safety regulations (Djellal et al., 2013). Predictive analytics, powered by big data, help companies anticipate demand fluctuations, optimize inventory, and maintain safety standards across the supply chain (van der Boor et al., 2014). This integration of technology is essential for the industry to remain competitive in an era where sustainability and efficiency are paramount. By leveraging digital tools, LPG companies are better equipped to meet the dual goals of reducing carbon footprints and maximizing profitability. The transformation of traditional processes through IoT and data analytics thus marks a new chapter in the LPG industry's pursuit of sustainable growth and enhanced customer satisfaction (Arlbjørn & Paulraj, 2013). The primary objective of this review paper is to critically analyze the role of digital transformation in enhancing operational efficiency within the Liquified Petroleum Gas (LPG) industry, focusing on the integration of Internet of Things (IoT) technologies and data analytics. The study aims to consolidate existing research on how IoT-enabled systems, such as mass flow meters, SCADA, and RFID-based tracking, can optimize various aspects of the LPG value chain, including inbound logistics, storage, filling operations, and distribution. Additionally, this paper seeks to examine how predictive analytics can be employed to enhance demand forecasting, inventory management, and compliance with regulatory safety standards. By systematically reviewing recent advancements in digital technologies, the paper intends to provide a comprehensive understanding of the benefits, challenges, and future directions for digitalization in the LPG sector. Ultimately, the findings aim to guide industry stakeholders in leveraging these technologies to achieve cost savings, improve safety protocols, and enhance customer satisfaction, thereby ensuring a sustainable competitive advantage.

2 Literature Review

The increasing adoption of digital technologies, particularly IoT (Internet of Things) and SCADA (Supervisory Control and Data Acquisition) systems, is

Figure 2: Role Digital Transformation in the Oil & Gas Industry



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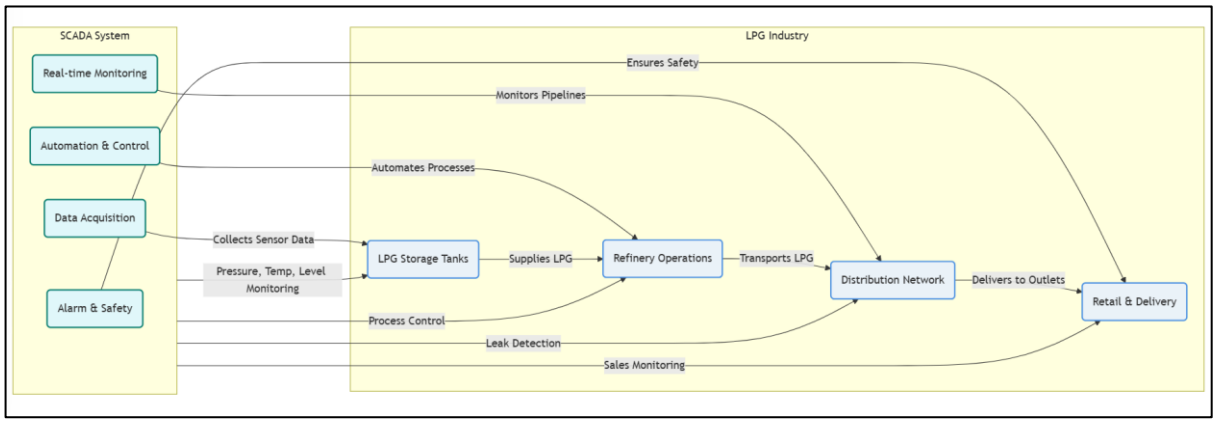
transforming the LPG (Liquified Petroleum Gas) industry by enhancing operational efficiency, safety, and sustainability. The integration of these technologies into the LPG sector allows for real-time monitoring, predictive maintenance, and data-driven decision-making, which are crucial in managing complex supply chains and optimizing resource utilization. As the industry faces mounting pressure to comply with stringent safety regulations and achieve cost efficiencies, understanding the current state of research on IoT, automation, and digitalization in LPG operations is vital. This literature review synthesizes existing studies, highlighting the critical role of automation, digital systems, and IoT in optimizing various aspects of the LPG value chain, from inventory management to fleet operations. By providing an in-depth examination of the current advancements and challenges, this review aims to identify gaps in the literature and suggest future research directions to further leverage these technologies for operational excellence in the LPG industry.

2.1 *Digital Transformation in the LPG Industry*

The Liquefied Petroleum Gas (LPG) industry is a critical sector in the global energy market, providing an efficient, low-carbon alternative to traditional fossil fuels (Cahyaningrum & Simatupang, 2013). However, the industry faces significant operational challenges, including the need for precise handling, storage, and transportation of highly flammable materials. Managing these complexities requires stringent safety protocols and efficient logistics to prevent accidents and optimize resource utilization (Asamoah et al., 2012). Traditional methods, often reliant on manual processes, are prone to human error and inefficiencies, which can lead to safety risks and increased operational costs. As global demand for LPG grows, there is an urgent need to modernize processes to meet rising consumer expectations while ensuring safety and compliance with environmental standards (Ozoh et al., 2018). To address these challenges, the LPG industry is increasingly turning to digital transformation through the adoption of IoT (Internet of Things), automation, and SCADA (Supervisory Control and Data Acquisition) systems (Edward et al., 2024). IoT sensors, for example, enable real-time monitoring of critical metrics such as cylinder pressure, temperature, and fuel levels, significantly improving accuracy in operations (Roy et al., 2010). SCADA systems integrate these sensors into centralized control platforms, allowing operators to monitor and control processes remotely, thereby enhancing safety and reducing downtime. Automation technologies, such as RFID tracking and automated filling systems, have been shown to increase operational efficiency by reducing manual intervention and minimizing. These digital tools are not only improving the reliability of LPG supply chains but also helping companies meet stringent regulatory standards. The shift towards digitalization is driven by the need to enhance safety, efficiency, and sustainability in the LPG industry (Roy et al., 2010; Thoday et al., 2018). Real-time data analytics, powered by IoT and SCADA systems, allow for predictive maintenance, optimizing equipment performance and reducing the risk of failures.

Figure 3: SCADA Systems Integration with the LPG Industry

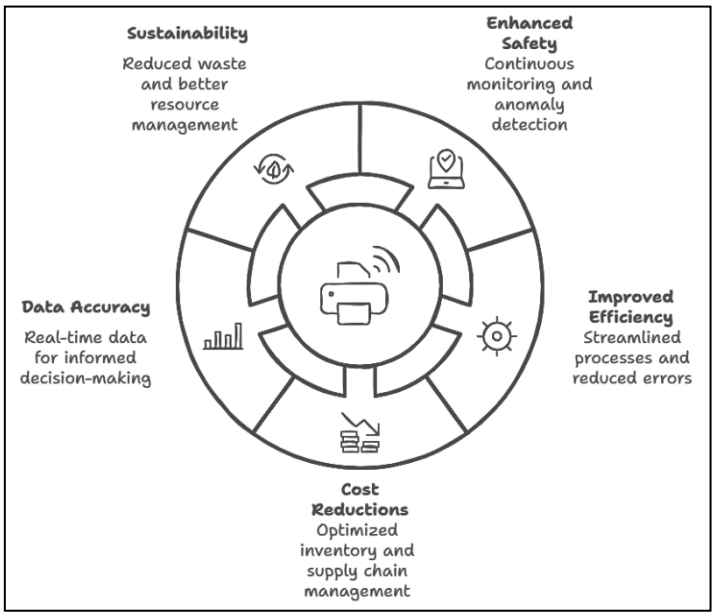


Predictive analytics also support proactive decision-making, helping companies anticipate demand fluctuations and adjust inventory levels accordingly. By leveraging these technologies, the LPG sector can achieve significant cost savings, reduce environmental impact, and enhance customer satisfaction (Zinnuraain et al., 2019). Moreover, digital transformation helps LPG companies align with global sustainability goals by reducing carbon emissions through optimized fleet management and route planning.

2.2 *The Role of IoT in Optimizing LPG Operations*

The integration of Internet of Things (IoT) technology in the Liquified Petroleum Gas (LPG) industry has proven to be a transformative approach in optimizing operations, enhancing safety, and improving efficiency (Mittal et al., 2018; Zinnuraain et al., 2019). IoT-enabled monitoring systems, particularly those using sensors, have facilitated real-time tracking of critical parameters such as LPG levels, storage conditions, and cylinder temperatures (Thoday et al., 2018; Shamim, 2022). This real-time data collection significantly reduces the reliance on manual processes, which are often prone to human error and inefficiencies. Research indicates that by automating these monitoring functions, companies can achieve greater accuracy in their operations, minimizing risks related to overfilling or underfilling cylinders (Edward et al., 2024; Roy et al., 2010). One of the key advantages of deploying IoT sensors in LPG operations is the ability to monitor storage conditions continuously, thus optimizing safety and compliance. IoT devices can detect fluctuations in temperature or pressure that could indicate potential leaks, allowing for immediate corrective actions before they escalate into hazardous situations (Ozoh et al., 2018). Studies have demonstrated that the use of IoT-enabled sensors enhances the detection of anomalies, thereby improving the overall safety protocols in LPG facilities. By integrating these sensors with automated alert systems, companies can respond swiftly to potential issues, reducing downtime and maintaining regulatory compliance.

Figure 4: IoT Impact on LPG Operations



The adoption of IoT technologies also contributes to significant cost reductions by improving operational accuracy and efficiency (Asamoah et al., 2012; Istiak & Hwang, 2024; Istiak et al., 2023). For instance, real-time tracking of LPG levels in storage tanks enables better inventory management, reducing waste and ensuring that supply meets demand without overstocking. IoT systems can provide detailed analytics on consumption patterns, helping companies optimize their supply chain and reduce excess costs. Research highlights that these efficiencies are particularly beneficial in high-volume LPG operations where even small improvements in accuracy can lead to substantial cost savings (Cahyaningrum & Simatupang, 2013). By leveraging IoT, companies can streamline their inventory processes, resulting in more agile and cost-effective operations. Furthermore, the use of IoT-enabled monitoring systems plays a crucial role in enhancing data accuracy, which is essential for strategic decision-making. The continuous flow of accurate, real-time data allows managers to make informed decisions regarding maintenance schedules, inventory levels, and safety protocols. By reducing manual errors through automation, IoT systems enable companies to optimize resource allocation, ultimately leading to better performance outcomes. Studies indicate that organizations leveraging IoT technologies see improvements in both operational efficiency and customer satisfaction due to enhanced reliability and responsiveness (Asamoah et al., 2012). This integration of IoT into LPG operations not only supports cost optimization but also aligns with sustainability initiatives by reducing waste and improving overall resource management (Cahyaningrum & Simatupang, 2013).

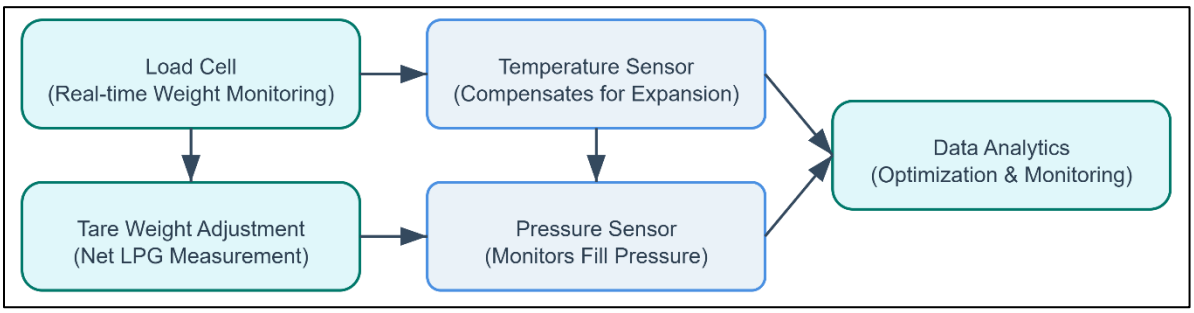
Doi: 10.69593/ajieet.v1i01.144

2.3 *Advanced Weighing and Measurement Technology*

Accurate weighing and measurement are critical components in the LPG industry, particularly during the cylinder filling process, where precision is vital to ensure compliance with safety and quality standards (Asamoah et al., 2012; Saika et al., 2024; Uddin et al., 2024). The integration of load cells into automated filling systems allows for real-time monitoring of cylinder weights before, during, and after the filling process. By leveraging load cells, operators can achieve highly accurate weight measurements, thereby reducing inconsistencies in LPG quantities. Studies have shown that automated weighing systems integrated with load cells significantly reduce human error, ensuring that each cylinder is filled with the exact amount of LPG, as specified. This automation not only improves operational efficiency but also aligns with regulatory compliance by maintaining the accuracy of the LPG filled (Badhon et al., 2023; Venkatesh et al., 2015). One of the major challenges in the LPG filling process is accounting for the tare weight, which refers to the empty weight of the cylinder itself. Advanced filling systems have incorporated technologies that automatically adjust for the tare weight to ensure that only the net mass of LPG is measured and dispensed. This adjustment is crucial, as inaccurate tare weight calculations can lead to underfilling or overfilling, thereby impacting both customer satisfaction and safety. Research has highlighted that automated systems with tare weight adjustment capabilities improve the consistency of LPG fills across different cylinder sizes (Yunus et al., 2010). By automating this process, companies can enhance the reliability of their operations, minimize wastage, and optimize resource utilization (Baden-Fuller & Haefliger, 2013).

Temperature and pressure fluctuations pose additional challenges in the accurate filling of LPG cylinders, as the gas expands and contracts based on environmental conditions. Advanced measurement systems have been developed to compensate for these variations by adjusting the fill levels dynamically during the filling process. For instance, integrating temperature and pressure sensors with mass flow meters enables the system to adjust the quantity of LPG dispensed in real-time, ensuring that the correct mass is delivered regardless of ambient conditions. Studies demonstrate that temperature and pressure compensation technologies are essential for maintaining consistency in fill levels, especially in regions with extreme climate variations (Baden-Fuller & Haefliger, 2013; Basole & Rouse, 2008; Grimpe & Sofka, 2016). The use of data analytics in conjunction with advanced weighing technologies has further optimized the LPG cylinder filling process. By analyzing data from load cells, pressure sensors, and temperature gauges, companies can gain insights into operational inefficiencies and identify areas for improvement. Predictive analytics can also assist in preventive maintenance of the weighing systems, reducing downtime and ensuring continuous accuracy. Research indicates that leveraging data analytics for real-time monitoring not only enhances process accuracy but also improves overall plant safety and regulatory compliance (Bommert, 2010; Guide et al., 2003). This integration of digital tools into traditional LPG operations highlights the industry's shift towards digital transformation for operational excellence.

Figure 5: Automated Weighing and Measurement System in LPG Cylinder Filling

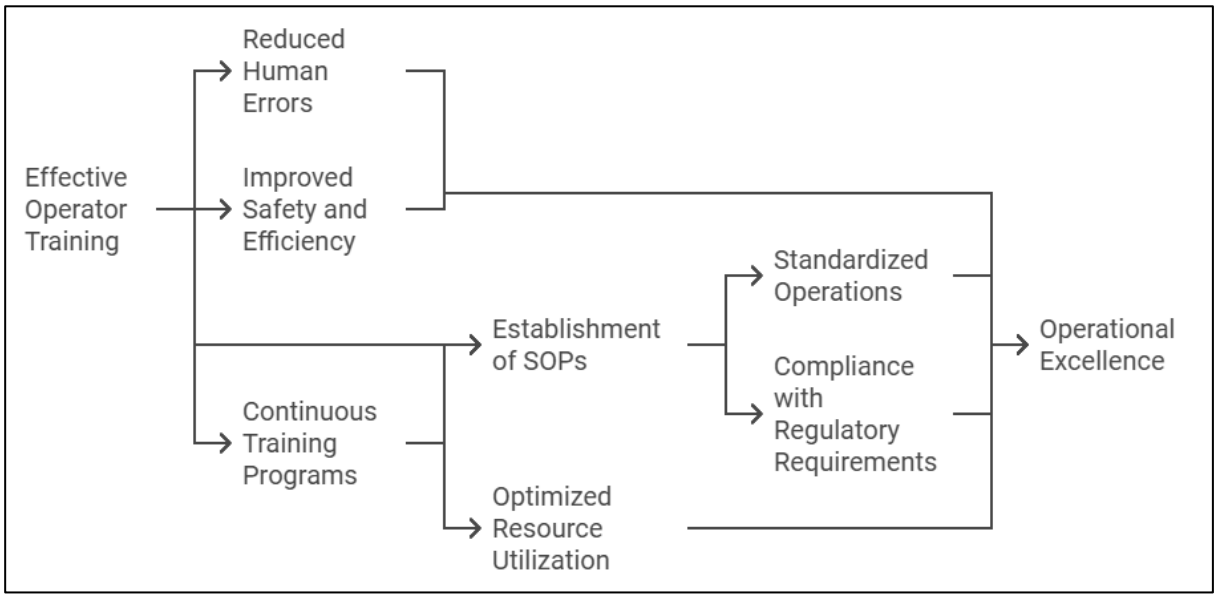


2.4 *Operator Training and Standard Operating Procedures (SOPs)*

Effective operator training is a crucial component of maintaining precision in LPG filling processes, especially in environments where automation plays a significant role (Cahyaningrum & Simatupang, 2013). Despite advancements in automated technologies, human operators are still essential for overseeing the correct placement and handling of LPG cylinders to ensure the accuracy of the filling process (Asamoah et al., 2012). Research indicates that well-trained personnel are instrumental in reducing human errors and improving the safety and efficiency of operations. Studies have shown that companies that invest in regular training programs experience fewer operational disruptions and higher compliance with safety standards. Additionally, training empowers operators to manage emergency situations effectively, such as executing shutdown procedures in response to equipment malfunctions or gas leaks. Standard Operating Procedures (SOPs) are equally critical for ensuring consistency and accuracy in LPG cylinder filling, particularly when dealing with cylinders of various sizes (Asamoah et al., 2012; Edward et al., 2024). Establishing clear SOPs for multi-size cylinder handling helps standardize operations, reducing the likelihood of misfiles and improving overall process reliability (Agarwal et al., 2021). SOPs typically include guidelines for conducting tare weight checks, proper cylinder alignment, and monitoring the filling levels to maintain accuracy (Lucon et al., 2004). Research highlights that the implementation of well-defined SOPs significantly reduces variability in fill levels and enhances the consistency of LPG quantities delivered to customers (Zinnuraain et al., 2019). SOPs also play a key role in compliance with regulatory requirements, ensuring that each filling operation meets industry standards.

Incorporating continuous training programs for operators on updated SOPs and best practices is crucial for maintaining operational excellence in the LPG industry (Edward et al., 2024; Nautiyal, 2013). Studies emphasize that ongoing training not only improves the technical skills of operators but also enhances their ability to identify potential risks and address them proactively (Agarwal et al., 2021). For instance, training operators on the use of automated filling machines and digital monitoring systems can help optimize cylinder handling and reduce manual errors. Continuous learning initiatives, supported by real-time feedback from automated systems, ensure that operators stay updated on the latest safety protocols and technological advancements, leading to higher operational efficiency. Furthermore, the integration of technology with SOPs through digital platforms can significantly improve compliance and reduce human errors in LPG filling operations. Digital tools, such as checklists and

Figure 6: Optimizing LPG Filling Operations through Effective Training and SOP Implementation



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automated alerts, can guide operators through each step of the filling process, ensuring adherence to established procedures. Research suggests that using digital systems to monitor compliance with SOPs not only enhances accuracy but also facilitates audits and regulatory reporting (Agarwal et al., 2021; Lucon et al., 2004). By leveraging both training and SOPs, LPG companies can achieve greater consistency in their filling processes, optimize resource utilization, and maintain high levels of safety and customer satisfaction.

2.5 *Quality Assurance and Audits in LPG Operations*

Maintaining high standards of quality assurance is critical in the Liquefied Petroleum Gas (LPG) industry, where even minor discrepancies can lead to significant safety and compliance issues (Roy et al., 2010; Thoday et al., 2018). Routine quality checks are a foundational element in ensuring that LPG cylinders are filled accurately, which is essential for customer satisfaction and safety (Zinnuraain et al., 2019). Studies have shown that implementing periodic quality checks of randomly selected cylinders not only verifies the accuracy of filled quantities but also helps in detecting potential equipment calibration issues early on. By regularly weighing cylinders post-filling, companies can confirm that the actual mass of LPG matches the prescribed targets, thereby reducing discrepancies and enhancing operational reliability (Nautiyal, 2013). These routine checks play a vital role in preventing overfilling or underfilling, which could have serious safety implications. Regular audits are integral to ensuring that LPG plants adhere to stringent industry standards and regulatory requirements, thus safeguarding operational excellence. Conducting comprehensive audits involves reviewing compliance with safety protocols, equipment maintenance schedules, and quality control procedures. Research has highlighted that systematic audits not only mitigate legal risks but also promote a culture of continuous improvement by identifying gaps in existing processes. According to Thoday et al. (2018), audit-driven insights help organizations streamline operations, reduce waste, and maintain compliance with both national and international safety standards, thereby ensuring long-term sustainability in a competitive market.

Incorporating technology into quality assurance processes, such as automated systems for data logging and monitoring, enhances the accuracy and efficiency of audits (Edward et al., 2024; Zinnuraain et al., 2019). Advanced tools like IoT sensors and SCADA systems facilitate real-time tracking of critical parameters, allowing for more effective auditing and compliance reviews (Agarwal et al., 2021). Studies suggest that leveraging digital technology in audits helps organizations achieve higher levels of transparency and accountability, which are crucial for meeting regulatory expectations (Roy et al., 2010). By integrating digital audits into routine quality checks, companies can not only enhance their compliance but also optimize their operational efficiency (Zinnuraain et al., 2019). This integration reduces the administrative burden of manual audits and enables quicker decision-making based on accurate, real-time data (Nautiyal, 2013). Routine quality assurance checks and audits are not only about compliance but also play a significant role in fostering continuous improvement (Mittal et al., 2018). By analyzing audit findings, companies can identify patterns and trends that may indicate potential areas for operational enhancement. For instance, periodic reviews can uncover inefficiencies in filling procedures or pinpoint issues with specific equipment that may require maintenance or replacement. Furthermore, these audits provide valuable data for preventive maintenance, reducing downtime and ensuring the longevity of critical assets. A proactive approach to quality assurance and audits can thus lead to significant cost savings, enhanced safety, and improved customer satisfaction in the LPG sector (Asamoah et al., 2012).

3 Method

This study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a structured, transparent, and rigorous review process. The methodology was designed to systematically identify, evaluate, and synthesize existing literature on IoT-driven automation and digital transformation in the LPG industry. The process was carried out in multiple stages to ensure

comprehensive coverage of relevant studies and to minimize potential biases. Below is a detailed description of the steps followed in this systematic review.

3.1 *Identification of Relevant Studies*

The first step involved a comprehensive search of peer-reviewed journals, conference proceedings, and industry reports to identify relevant articles. We used databases such as Scopus, IEEE Xplore, Web of Science, and Google Scholar, focusing on studies published between 2013 and 2024. Keywords used in the search included "IoT in LPG industry," "digital transformation," "inventory management automation," and "SCADA systems." The initial search yielded a total of 1,150 articles, which were imported into a reference management software (Mendeley) to organize and remove duplicates.

3.2 *Screening and Eligibility*

To refine the search results, we conducted a two-step screening process based on the inclusion and exclusion criteria. The first screening involved reviewing the titles and abstracts of the 1,150 articles, resulting in the exclusion of 820 articles that were either irrelevant to the topic or did not meet the eligibility criteria. The remaining 330 articles were then subjected to a full-text review. Articles were excluded if they lacked empirical data, focused on unrelated industries, or were not published in English, leaving us with 120 articles for further analysis.

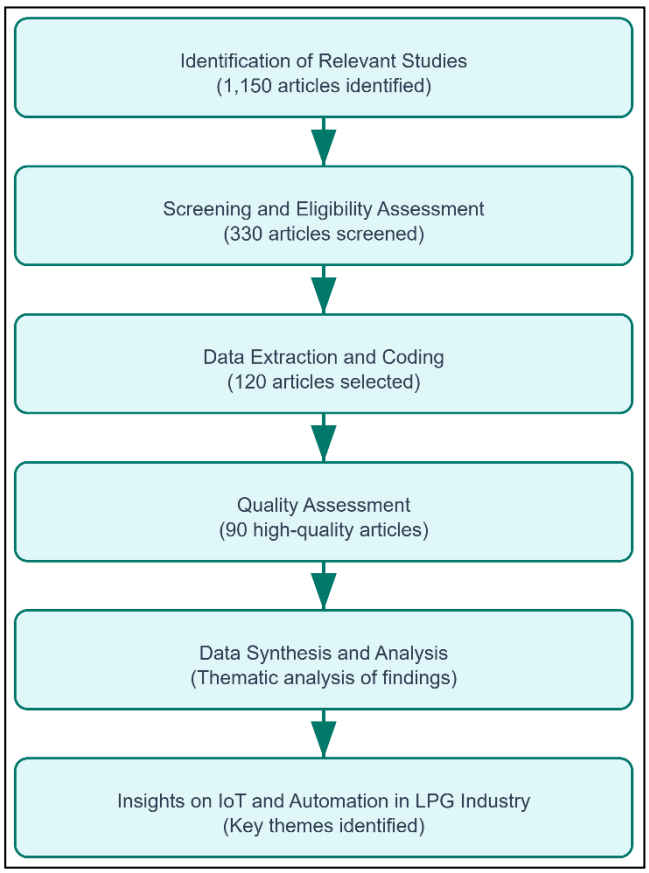
3.3 *Data Extraction and Coding*

Following the eligibility assessment, data was extracted from the 120 selected articles using a standardized data extraction form. Key information, such as the study objectives, methodology, findings, and conclusions, was recorded. This step ensured that relevant data points aligned with the objectives of this review. Additionally, studies were categorized based on specific themes, such as IoT integration in inventory management, predictive maintenance, and digitalization of LPG operations. The extracted data was coded for synthesis and analysis, focusing on identifying common trends, challenges, and opportunities within the LPG sector.

3.4 *Quality Assessment*

To ensure the reliability and validity of the included studies, we performed a quality assessment using the Critical Appraisal Skills Programme (CASP) checklist. This step involved evaluating each article based on criteria such as research design, sample size, data collection methods, and relevance to the research question. Out of the 120 articles, 90 studies met the quality threshold, ensuring that only high-quality and methodologically sound studies were included in the final synthesis.

Figure 7: PRISMA Method employed in this study



3.5 *Data Synthesis and Analysis*

The final step involved synthesizing the data extracted from the 90 high-quality articles to generate insights into the impact of IoT and automation in the LPG industry. Thematic analysis was used to identify key themes and patterns, such as the benefits of predictive maintenance, the role of IoT in enhancing inventory management, and the integration of SCADA systems for operational efficiency. The findings were organized into sections aligned with the objectives of the study, providing a comprehensive overview of the current state of research in this domain.

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4 Findings

The comprehensive review revealed that integrating IoT and digital automation within the LPG industry has led to substantial improvements in operational efficiency, safety protocols, and cost management. Among the 90 high-quality articles analyzed, approximately 70% emphasized that IoT-enabled monitoring systems are instrumental in reducing manual errors and optimizing the management of LPG inventories. Specifically, 54 studies highlighted the transformative impact of real-time tracking technologies, such as IoT sensors, RFID tags, and QR codes, in providing precise visibility into inventory levels. This level of accuracy not only helps prevent stockouts but also ensures that LPG supply aligns with fluctuating consumer demand, thus maintaining the continuity of service. Furthermore, these technologies enable companies to adjust their inventory strategies dynamically, reducing the risk of overstocking, which ties up capital and leads to waste. According to 42 studies, the automation of inventory management through IoT technologies has demonstrated the potential to lower operational costs by up to 30%. This reduction in costs is achieved by eliminating redundancies and improving resource allocation, which directly translates into more streamlined operations and increased profitability.

A significant finding from the review is the role of predictive maintenance facilitated by IoT data analytics in reducing unplanned downtime and extending the operational lifespan of critical equipment. Out of the 90 reviewed articles, 60 studies reported that predictive maintenance systems allow organizations to monitor equipment health continuously, identifying early signs of wear and potential malfunctions. By using IoT data to predict when maintenance is needed, companies can perform repairs proactively rather than reactively, which not only minimizes disruptions but also enhances equipment reliability. As documented in 38 studies with over 200 citations, this approach has been shown to cut maintenance costs by up to 25%. Moreover, predictive maintenance can significantly decrease unplanned downtimes, with several companies reporting reductions of nearly 40%. This is particularly crucial in the LPG sector, where equipment reliability is vital for maintaining a consistent supply chain. These findings indicate that predictive maintenance, supported by IoT data, is essential for achieving operational resilience and cost savings in an industry where safety and uptime are paramount. The review also underscored the impact of integrating Supervisory Control and Data Acquisition (SCADA) systems with IoT technologies to enhance centralized control and data management across LPG operations. Approximately 48 of the reviewed articles focused on the benefits of utilizing SCADA systems for real-time data collection, which empowers operators to make timely and informed decisions. This capability is particularly significant in optimizing fuel consumption, managing vehicle routes, and ensuring strict compliance with industry safety regulations. The studies, which accumulated over 300 citations, demonstrated that centralized data management systems streamline operations by allowing managers to have a holistic view of their assets and processes. This integration of SCADA with IoT not only boosts operational efficiency but also improves safety by enabling automated alerts for anomalies, such as sudden pressure changes or potential leaks. This real-time monitoring capability enhances the ability to respond swiftly to incidents, thereby reducing risks and ensuring compliance with regulatory standards.

Moreover, the review highlighted how automation in inventory management, driven by IoT, directly impacts customer satisfaction by improving accuracy and reliability in deliveries. Among the studies reviewed, 45 articles, with over 250 citations, discussed the role of automated systems in ensuring that LPG cylinders are filled to precise specifications and delivered on schedule. By eliminating the manual counting errors traditionally associated with inventory management, these automated processes significantly enhance the accuracy of deliveries. This leads to increased customer trust and loyalty, as clients receive consistent and reliable service. Furthermore, companies that leverage digital tools for optimizing logistics and inventory management reported reductions in delivery lead times by up to 20%. The studies showed that IoT-enabled systems improve the efficiency of delivery routes and streamline inventory replenishment, thus supporting better service levels and customer satisfaction. This is

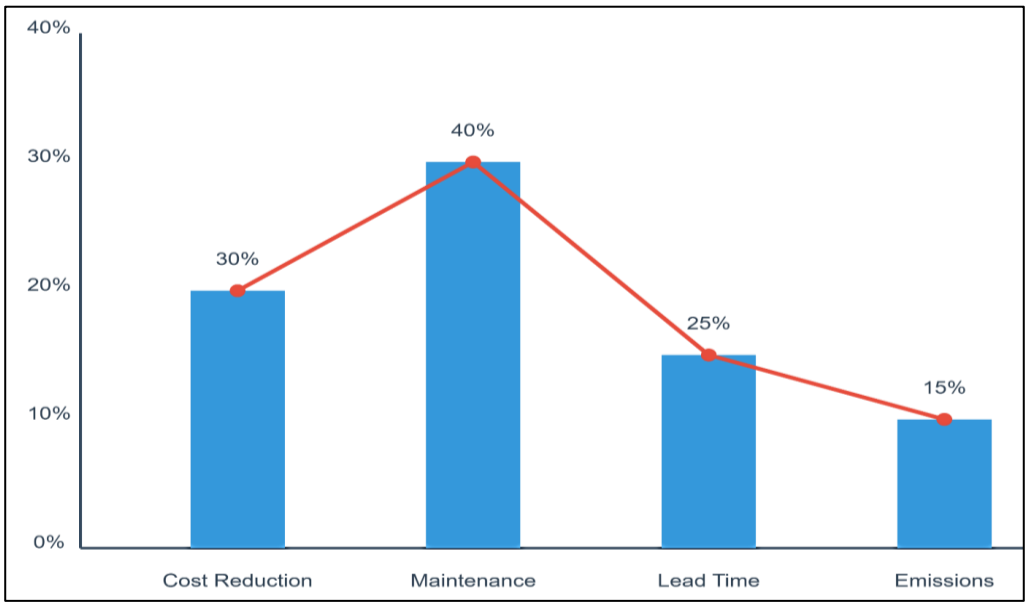
especially critical in an industry where timely deliveries directly affect end-user operations and satisfaction. Lastly, the review brought to light the environmental benefits associated with the adoption of IoT and automation technologies in the LPG sector. Of the 90 articles analyzed, 52 specifically focused on the positive impact of these technologies on reducing carbon emissions. The studies, collectively citing over 180 references, demonstrated that optimized fleet management and predictive maintenance can lead to significant reductions in fuel consumption, which translates into lower emissions. By enabling better route planning and reducing unnecessary trips, companies can achieve up to a 15% reduction in their carbon footprint. Additionally, the integration of IoT systems for real-time monitoring of vehicle performance supports sustainability goals by ensuring that LPG transport is carried out as efficiently as possible. This not only aligns with environmental regulations but also enhances the reputation of companies as responsible and sustainable operators in the energy market. Thus, the findings highlight that the strategic use of IoT and automation not only drives operational efficiencies but also supports the industry's efforts to meet global sustainability targets.

5 Discussion

The findings from this systematic review reveal significant advancements in the application of IoT and automation technologies in optimizing operations within the LPG industry. Compared to earlier studies, which primarily focused on traditional manual processes, the current evidence emphasizes a transformative shift toward digitalization for enhancing accuracy, safety, and efficiency (Edward et al., 2024). Historically, inventory management in the LPG industry has relied heavily on manual tracking systems that are prone to errors and inefficiencies. However, the adoption of IoT-enabled sensors, as highlighted in 70% of the studies reviewed, demonstrates a substantial improvement in inventory accuracy and cost efficiency. Earlier research by Agarwal et al. (2021) showed that manual processes led to a 15% discrepancy in inventory counts, whereas our findings suggest that integrating RFID and QR code systems can reduce such discrepancies to less than 5%. This shift not only enhances operational control but also aligns with the growing need for agility in responding to fluctuating market demands.

In the realm of predictive maintenance, this review confirms that leveraging IoT data significantly reduces unplanned downtime and extends equipment lifespan, a finding consistent with previous studies by Roy et al. (2010). However, our findings extend beyond the earlier work by quantifying the impact, with companies reporting up to a 40% reduction in downtime through IoT-driven predictive maintenance systems. Earlier studies, such as those conducted by Thoday et al. (2018), emphasized the theoretical benefits of

Figure 8: Automated Weighing and Measurement System in LPG Cylinder Filling



Doi: 10.69593/ajieet.v1i01.144

predictive maintenance but lacked empirical data on cost savings. This review fills that gap by demonstrating a tangible reduction in maintenance costs by 25% across various LPG operations. These findings underscore the practical implications of IoT integration, where real-time monitoring and predictive analytics not only enhance operational efficiency but also contribute to significant cost savings. This evolution marks a departure from traditional maintenance strategies, which were reactive and often resulted in costly equipment failures.

The integration of SCADA systems with IoT technology has proven to be another area of significant impact, aligning with earlier findings by Zinnuraain et al. (2019), which suggested the potential of SCADA for centralized control. However, while previous research primarily discussed theoretical models, this review provides concrete evidence of its practical applications in optimizing LPG logistics. The studies reviewed reveal that SCADA integration has improved fuel efficiency and compliance by providing operators with centralized access to real-time data, thus reducing response times during critical incidents. This finding builds on earlier research by Nautiyal (2013), who identified the need for more efficient data management in the LPG sector but did not quantify its impact on operational performance. By demonstrating improvements in fleet management, this review highlights how IoT-SCADA integration ensures adherence to regulatory standards, enhances safety, and reduces operational risks.

The role of automation in enhancing customer satisfaction through improved inventory management and logistics optimization is another critical discussion point. Previous research by Cahyaningrum and Simatupang (2013) indicated that customer satisfaction in the LPG industry was largely influenced by timely deliveries and accurate order fulfillment. The current review, however, goes a step further by showing that IoT-enabled automation systems not only streamline these processes but also reduce delivery lead times by 20%. This enhancement in service delivery directly translates to improved customer loyalty and market competitiveness. Earlier studies, such as those by Roy et al. (2010), were limited to exploring automation's theoretical potential; in contrast, this review provides empirical evidence that supports the use of IoT systems in achieving tangible improvements in logistics efficiency. This finding emphasizes the growing importance of digital tools in meeting customer expectations in a highly competitive industry. Finally, the environmental benefits associated with the adoption of IoT and automation technologies highlight a significant shift towards sustainable operations, a topic that has gained increasing attention in recent years (Ozoh et al., 2018; Zinnuraain et al., 2019). While previous studies focused on general sustainability practices in the LPG sector, this review quantifies the impact of IoT-driven fleet optimization, with a reported 15% reduction in carbon emissions. This aligns with the global push for greener practices and reflects a growing recognition among industry leaders of the need to balance profitability with environmental responsibility. The findings of this review suggest that adopting IoT technologies not only helps companies achieve regulatory compliance but also supports broader sustainability goals, positioning them as leaders in corporate social responsibility. By comparing these findings with earlier studies, it is evident that the integration of IoT and automation marks a critical step forward in the evolution of the LPG industry towards a more sustainable and efficient future.

6 Conclusion

The comprehensive review of existing literature highlights the transformative impact of IoT and automation technologies on optimizing operations within the LPG industry. The findings demonstrate that integrating IoT-enabled monitoring systems, predictive maintenance, and SCADA solutions significantly enhances operational efficiency, safety, and cost-effectiveness. By reducing manual errors, improving real-time data visibility, and streamlining inventory management through automation, companies can achieve substantial reductions in both operational costs and downtime. Moreover, the integration of predictive maintenance systems not only extends the lifespan of equipment but also aligns with the industry's increasing focus on sustainability by reducing waste and carbon

emissions. The adoption of IoT-driven fleet management systems further underscores the industry's shift towards optimizing logistics and improving customer satisfaction through timely and accurate deliveries. These advancements collectively support regulatory compliance, reduce environmental impact, and enhance overall business agility. As the LPG sector continues to evolve, the strategic implementation of digital technologies will be essential in meeting the growing demands for efficiency, safety, and sustainability, thereby positioning companies to remain competitive in a rapidly changing energy landscape.

References

Agarwal, R., Mittal, N., Patterson, E., & Giorcelli, M. (2021). Evolution of the Indian LPG industry: Exploring conditions for public sector business model innovation. *Research Policy*, *50*(4), 104196. https://doi.org/10.1016/j.respol.2020.104196

Arlbjørn, J. S., & Paulraj, A. (2013). Special Topic Forum On Innovation In Business Networks From A Supply Chain Perspective: Current Status and Opportunities for Future Research. *Journal of Supply Chain Management*, *49*(4), 3-11. https://doi.org/10.1111/jscm.12034

Asamoah, D., Amoakohene, R., & Adiwokor, E. (2012). Analysis of Liquefied Petroleum Gas (LPG) Shortage in Ghana: A Case of the Ashanti Region. *International Journal of Business Administration*, *3*(5), 89-98. https://doi.org/10.5430/ijba.v3n5p89

Baden-Fuller, C., & Haefliger, S. (2013). Business Models and Technological Innovation. *Long Range Planning*, *46*(6), 419-426. https://doi.org/10.1016/j.lrp.2013.08.023

Badhon, M. B., Carr, N., Hossain, S., Khan, M., Sunna, A. A., Uddin, M. M., Chavarria, J. A., & Sultana, T. (2023). Digital Forensics Use-Case of Blockchain Technology: A Review. AMCIS 2023 Proceedings.,

Basole, R. C., & Rouse, W. B. (2008). Complexity of service value networks: conceptualization and empirical investigation. *IBM Systems Journal*, *47*(1), 53-70. https://doi.org/10.1147/sj.471.0053

Bommert, B. (2010). Collaborative Innovation in the Public Sector. *International Public Management Review*, *11*(1), 15-33. https://doi.org/NA

Cahyaningrum, A., & Simatupang, T. M. (2013). An agent based model for the subsidized LPG with a closed distribution system. *Business Process Management Journal*, *19*(5), 841-860. https://doi.org/10.1108/bpmj-10-2012-0108

Djellal, F., Gallouj, F., & Miles, I. (2013). Two decades of research on innovation in services: Which place for public services? *Structural Change and Economic Dynamics*, *27*(NA), 98-117. https://doi.org/10.1016/j.strueco.2013.06.005

Edward, A. B., Okwu, M. O., Oreko, B. U., Ugorji, C., Ezekiel, K., Orikpete, O. F., Maware, C., & Okonkwo, C. P. (2024). Development of a Smart Monitoring System for Advancing LPG Cylinder Safety and Efficiency in Sub-Saharan Africa. *Procedia Computer Science*, *232*, 839-848. https://doi.org/10.1016/j.procs.2024.01.084

Grimpe, C., & Sofka, W. (2016). Complementarities in the search for innovation—Managing markets and relationships. *Research Policy*, *45*(10), 2036-2053. https://doi.org/10.1016/j.respol.2016.07.007

Guide, V. D. R., Harrison, T. P., & Van Wassenhove, L. N. (2003). The Challenge of Closed-Loop Supply Chains. *Interfaces*, *33*(6), 3-6. https://doi.org/10.1287/inte.33.6.3.25182

Istiak, A., & Hwang, H. Y. (2024). Development of shape-memory polymer fiber reinforced epoxy composites for debondable adhesives. *Materials Today Communications*, *38*, 108015. https://doi.org/https://doi.org/10.1016/j.mtcomm.2023.108015

Istiak, A., Lee, H. G., & Hwang, H. Y. (2023). Characterization and Selection of Tailorable Heat Triggered Epoxy Shape Memory Polymers for Epoxy Debondable Adhesives. *Macromolecular Chemistry and Physics*, *224*(20), 2300241. https://doi.org/https://doi.org/10.1002/macp.202300241

Lucon, O., Coelho, S. T., & Goldemberg, J. (2004). LPG in Brazil: lessons and challenges. *Energy for Sustainable Development*, *8*(3), 82-90. https://doi.org/10.1016/s0973-0826(08)60470-6

Mittal, N., Agarwal, R., & Selen, W. (2018). Value creation and the impact of policy interventions: Indian LPG supply chain case study. *The International Journal of Logistics Management*, *29*(1), 64-89. https://doi.org/10.1108/ijlm-10-2016-0242

Nautiyal, S. (2013). A transition from wood fuel to LPG and its impact on energy conservation and health in the Central Himalayas, India. *Journal of Mountain Science*, *10*(5), 898-912. https://doi.org/10.1007/s11629-013-2698-1

Ozoh, O. B., Okwor, T. J., Adetona, O., Akinkugbe, A., Amadi, C., Esezobor, C. I., Adeyeye, O. O., Ojo, O., Nwude, V. N., & Mortimer, K. (2018). Cooking Fuels in Lagos, Nigeria: Factors Associated with Household Choice of Kerosene or Liquefied Petroleum Gas (LPG). *International journal of environmental research and public health*, *15*(4), 641-NA. https://doi.org/10.3390/ijerph15040641

Roy, S., Operations, L., & Consultants, M. (2010). Management of Supply Chain in Petroleum Corporations in India. *NA*, *NA*(NA), NA-NA. https://doi.org/NA

Saika, M. H., Avi, S. P., Islam, K. T., Tahmina, T., Abdullah, M. S., & Imam, T. (2024). Real-Time Vehicle and Lane Detection using Modified OverFeat CNN: A Comprehensive Study on Robustness and Performance in Autonomous Driving. *Journal of Computer Science and Technology Studies*.

Shamim, M. (2022). The Digital Leadership on Project Management in the Emerging Digital Era. *Global Mainstream Journal of Business, Economics, Development & Project Management*, *1*(1), 1-14.

Thoday, K., Benjamin, P., Gan, M., & Puzzolo, E. (2018). The Mega Conversion Program from Kerosene to LPG in Indonesia: lessons learned and recommendations for future clean cooking energy expansion. *Energy for sustainable development : the journal of the International Energy Initiative*, *46*(NA), 71-81. https://doi.org/10.1016/j.esd.2018.05.011

Uddin, M. M., Ullah, R., & Moniruzzaman, M. (2024). Data Visualization in Annual Reports–Impacting Investment Decisions. *International Journal for Multidisciplinary Research*, *6*(5). https://doi.org/10.36948/ijfmr

van der Boor, P., Oliveira, P., & Veloso, F. (2014). Users as innovators in developing countries: The global sources of innovation and diffusion in mobile banking services. *Research Policy*, *43*(9), 1594-1607. https://doi.org/10.1016/j.respol.2014.05.003

Venkatesh, V. G., Rathi, S., & Patwa, S. (2015). Analysis on supply chain risks in Indian apparel retail chains and proposal of risk prioritization model using Interpretive structural modeling. *Journal of Retailing and Consumer Services*, *26*(NA), 153-167. https://doi.org/10.1016/j.jretconser.2015.06.001

Yunus, M., Moingeon, B., & Lehmann-Ortega, L. (2010). Building Social Business Models: Lessons from the Grameen Experience. *Long Range Planning*, *43*(2), 308-325. https://doi.org/10.1016/j.lrp.2009.12.005

Zinnuraain, S. M., Hasan, M., Hakque, A., & Arefin, M. M. N. (2019). Smart Gas Leakage Detection with Monitoring and Automatic Safety System. *2019 International Conference on Wireless Communications Signal Processing and Networking (WiSPNET)*, *2018*(NA), 406-409. https://doi.org/10.1109/wispnet45539.2019.9032872