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THE IMPACT OF DIGITALIZATION INTEGRATION ON OPERATIONAL EFFECTIVENESS AT GAS STATIONS (SPBU)

[1]**Pesta Damayanti**,[2]**Prihatin Lumbanraja**,[3]**Amlys Syahputra Silalahi**

[1,2,3]*Management Science, Faculty of Economics and Business, University Sumatera Utara, Medan, Indonesia*

Author's email:
[1]pesta151186@gmail.com

Corresponding author: pesta151186@gmail.com

Abstract. *The Fourth Industrial Revolution and the rapid acceleration of digital transformation, especially post-pandemic, have compelled various industries, including gas stations (SPBU), to adopt digital technologies to enhance operational effectiveness. Recent phenomena, such as the rise of cashless transactions, automated inventory management, and the Internet of Things (IoT), reflect a growing demand for efficiency, accuracy, and customer satisfaction in service sectors. This study aims to analyze the impact of digital integration on SPBU operational effectiveness using a systematic literature review (SLR) approach. Data were collected from relevant scientific journals over the last decade, focusing on digitalization in energy and public service industries. The findings reveal that digital technology adoption—such as electronic payment systems, IoT-based fuel monitoring, and ERP-driven inventory optimization—significantly improves operational performance. Key improvements include faster service delivery, cost efficiency, and enhanced inventory accuracy, contributing to higher customer satisfaction. However, challenges persist, such as high investment costs and workforce adaptability to digital systems. This study offers practical recommendations for SPBU managers to align with emerging digital trends, ensuring competitiveness and operational excellence in an increasingly digital economy.*

Keywords: *Cashless Transaction, Digitalization, Operational Effectiveness, loT, SPBU.*

1. INTRODUCTION

The Fourth Industrial Revolution has brought significant changes to various economic sectors worldwide. This era is characterized by the integration of digital technology, automation, the Internet of Things (IoT), artificial intelligence (AI), big data, and cyber-physical systems, which create higher efficiency and productivity. In January 2016, Klaus Schwab, the Founder and Executive Chairman of the World Economic Forum, released his book titled The Fourth Industrial Revolution (Prestidge, 2021) explains that the Fourth Industrial Revolution not only transforms the way we work but also reshapes management systems, human interactions, and business processes

Klaus Schwab (Peskova et al., 2019) highlighted the transformative impact of digital technologies, emphasizing that the advancement of the modern economy is closely tied to the extent of digital transformation. He noted that "new technologies, along with the social groups they foster and the interactions they enable, empower nearly anyone to influence circumstances in ways that would have been unimaginable just a few years ago."

In the global context, developed countries such as Germany, Japan, and the United States have initiated digital transformations in their strategic industries. For instance, Klaus Schwab highlighted the transformative impact of digital technologies, emphasizing that the advancement of the modern economy is closely tied to the extent of digital transformation. He noted that "new technologies, along with the social groups they foster and the interactions they enable, empower nearly anyone to influence circumstances in

ways that would have been unimaginable just a few years ago." Germany's Industrie 4.0 initiative has driven the use of advanced technology-based production systems to enhance the competitiveness of its manufacturing industry. Similarly, China, through its Made in China 2025 policy, IoT applications are gaining widespread popularity and, when effectively implemented, can result in substantial revenue growth. (Nassif, 2018)

In the energy sector, particularly in fuel distribution, the Fourth Industrial Revolution opens opportunities to enhance operational effectiveness through digital technology utilization. Technologies such as the precision in dispensing wet stock at the fuel pump (TopUniversities, 2022), digital payment options (Ahmed, n.d.), and data integration via IoT-based platforms have proven effective in reducing operational inefficiencies and improving customer satisfaction. In developed countries, gas stations have transitioned to self-service systems equipped with automatic payment technologies and digital stock monitoring, allows companies to enhance energy production and distribution, track equipment performance, improve workplace health, and minimize downtime. (Sustainability & Practices, 2024)

In Indonesia, government policies on digitalization are reflected in the Making Indonesia 4.0 program, launched by the Ministry of Industry in 2018. This policy aims to encourage digital transformation in priority industrial sectors, including energy, manufacturing, and logistics. Through Making Indonesia 4.0, the government is committed to optimizing digital technology utilization to support operational effectiveness and efficiency within Indonesian companies.

Furthermore, in recent years, digital transformation policies have been reinforced through various regulations, such as:

- Presidential Regulation No. 95 of 2018 on the Electronic-Based Government System (SPBE), which promotes the digitalization of work processes in both public and private sectors.
- The Strategic Plan of the Ministry of Energy and Mineral Resources (ESDM), emphasizing the importance of digitalization in gas station operational management.
- The Digital Talent Scholarship program by the Ministry of Communication and Information Technology, aimed at enhancing workforce competence to face digitalization.

However, considering these factors, fuel retail companies are in a delicate position, requiring them to adapt and invest to attract and retain customers for their survival. (Panduru & Scarlat, 2022)

The implementation of these digitalization policies faces several challenges, including employee resistance to technological changes, limitations in digital infrastructure, and the lack of workforce skills to adopt new technologies. These challenges are particularly relevant in the gas station sector, which plays a crucial role in supporting the national energy distribution system.

2. LITERATURE REVIEW

The reviewed literature highlights diverse approaches to understanding the role of digitalization in enhancing operational effectiveness at SPBU. Key themes include the adoption of digital technologies, customer satisfaction, operational efficiency, and safety enhancements. Below, we summarize the major findings:

2.1 Adoption of Digital Technologies

Echnological adoption has emerged as a primary driver of operational effectiveness. Studies such as (Xiong et al., 2018) and (Amada et al., 2024) emphasize the transformative potential of IoT and big data in enabling real-time monitoring and predictive maintenance. highlights digital twin technology (Jia et al., 2024) as a tool to

improve safety and operational precision. These technologies allow gas stations to optimize resource allocation and minimize downtime.

2.2 Customer Satisfaction

Customer-focused innovations such as digital payment systems and personalized experiences significantly contribute to operational success. Gumelar (Gumelar et al., 2023) and Nirwana (Nirwana et al., 2024) found a positive correlation between digital services and customer satisfaction. Non-cash payment options and automated service enhancements streamline the customer journey, fostering loyalty and repeat visits.

2.3 Operational Efficiency

Digitalization enables gas stations to achieve streamlined workflows and enhanced operational efficiency. Panduru & Scarlat (2022) and Prestidge (Prestidge, 2021) discuss how digital tools facilitate strategic decision-making and process optimization. (Amanda et al., 2024) emphasize the role of IoT and big data in optimizing fuel distribution and reducing operational costs.

2.4 Safety Enhancements

Safety improvements are another critical area influenced by digitalization. Demonstrates how digital twins can predict and prevent safety incidents, ensuring compliance with safety standards (Jia et al., 2024). Such advancements reduce risks and enhance the overall reliability of SPBU operations.

Table 1. Oveview of Key Studies

No	Year	Title	Author	Country	Method	Research Intrument	Software
1	2016	Critical Review Of Petrol Station Management System With Emphasis On The Advantages If Digitalized In Nigeria	Anayo et al (Henry Anayo et al., 2016)	Nigeria	Qualitative	Structured System Analysis and Design Methodology	SDLC
2	2017	Internet of Things Remote Intelligent Monitor System of Oil & Gas Field	Xiong et al (Xiong et al., 2018)	China	Qualitative	RTU and DTU tools	analyzing
3	2018	Data Analysis From an Internet Of Things System in a Gas Station Convenience Store	Georges Nassif (Nassif, 2018)	Canada	Qualitative and quantitative	bluetooth beacon	RSSI
4	2019	The Driver of Development and Transformation of Global Oil and Gas Business in Digital Economy's Conditions	Peskova et al (Peskova et al., 2019)	Russia	Qualitative	CERA, Accenture, Deloitte, Pwc	analyzing
5	2019	Development of digital economy in the energy industry-specific modernization	Kapitonov et al (Kapitonov et al., 2019)	Russia	Qualitative	economic forecasts, and energy consumption records.	Normative-targeted and complex mathematical methods
6	2019	Designing a Mobile Digital Payment Application for Gas Stations in	Aimana Ilman Aulia (Aulia, 2019)	Netherland	Qualitative	survey and interviews	metrics

		Indonesia					
7	2019	Digitalization and Public Services: A Labour Perspective	Eckhard Voss and Raquel Rego (Eckhard Voss and Raquel Rego, 2019)	Portugal	Qualitative	Semi-structured questionnaire	Unidentified
8	2021	Mapping the Public- Private Partnership in Digitalization of PT. Pertamina Gas Station in Indonesia	Kusuma et al (Kusuma et al., 2022)	Indonesia	Qualitative	Systematic reviews of original, review, and report articles.	NVIVO 12 software
9	2021	Research on Influencing Factors of Service Interactive Experience of Digital Gas Station—The Case from China	Fang Li et al (Li & Pan, 2021)	China	Qualitative	Semi-structured questionnaire	NVivo12.0
10	2022	Digitalization and Strategic Changes in Romanian Retail Fuel Networks	Dan Andrei Panduru and Cezar Scarlat (Panduru & Scarlat, 2022)	Romania	Qualitative	Semi-structured questionnaire	analyzing
11	2022	An Analysis on Critical Determination Factors of E-Participation for Digital Society: The Case of Malaysian Local Government	Rizki Hashi Wiyantirta and Dendi P. Ishak (Wiyantirta & Ishak, 2023)	Malaysia	Qualitative	Observation	analyzing
12	2022	Digital Transformation in the Oil and Gas Industry: Challenges and Potential Solutions	Kelsey L. Prestidge (Prestidge, 2021)	America	Qualitative	Personal experience and observations	DSM
13	2022	Strategic Investment Analysis for the Gas Station Projects Using Build Operate and Transfer (Case Study: PT Pertamina, Besakih Bali)	Wulandari et al (Wulandari, 2022)	Indonesia	Qualitative and quantitative	strategic analysis and the purpose sampling method consisting of 2 people	PESTLE analysis, competition and risk analysis based on porter's five, and financial review
14	2022	Implementation of Discourse Network Analysis Related to News regarding PT Pertamina's Consumer Needs, Satisfaction, and Engagement	Fernandes et al (Fernandes et al., 2022)	Indonesia	Qualitative	Observation	DNA
15	2022	Analysis of Digitalization Service Quality of Fuel Petrol Station in Indonesia Using SERVQUAL Integrated BWM	Wiyantirta et al (Wiyantirta & Ishak, 2023)	Indonesia	Qualitative	SERVQUAL integrated BWM	analyzing

16	2022	Islamic Law Perspective in the Application of My Pertamina as a Non-Cash Payment System and Control of Fuel Subsidy Flow	Apriantoro et al (Apriantoro et al., 2022)	Indonesia	Qualitative	Journals, books, theses, theses, dissertations, and websites	analyzing
17	2023	A Review of Modern Approaches of Digitalization in Oil and Gas Industry	Salam Al-Rbeawi (Al-Rbeawi, 2023)	Iraq	Qualitative	Observation	analyzing
18	2023	Pengaruh digitalisasi SPBU dan kualitas pelayanan terhadap kepuasan konsumen	Gumelar et alv(Gumelar et al., 2023)	Indonesia	Quantitative	Questionnaire	Regresi linier berganda
19	2023	Effect of Customer Service Modernization on Customer Satisfaction in Shell Petrol Stations in Oman	TALAL ALI HASHIM AL BALUS (TopUniversities, 2022)	Dubai	Quantitative	Questionnaire	Regression analysis
20	2023	Digital twin technology and ergonomics for comprehensive improvement of safety in the petrochemical industry	Ziyu Liu (Jia et al., 2024)	China	Qualitative	Observation	ANFIS method
21	2024	Research on modeling method for digitizing distribution substation areas based on big data from smart meters	Bai et al (Bai et al., 2024)	China	Qualitative	Big data from smart meters	mathematical models and algorithms
22	2024	Digital Transformation at Fuel Stations in Sulaymaniyah, Kurdistan Iraq - Petro-retails Experience on Adoption of Digital Payment by the Consumers.	Twana Nasih Ahmed, Sabat Salih Muhamad (Ahmed, n.d.)	Iraq	Quantitative	Questionnaire	Regression analysis and ANOVA
23	2024	Operational Process Optimization by Combining IoT and Big Data Technology: A Case Study on PT Pertamina in the Oil and Gas Industry	Amanda et al (Amanda et al., 2024)	Indonesia	Qualitative	Observation	analyzing
24	2024	Pengaruh Kepuasan Konsumen SPBU melalui Digitalisasi dan Kualitas Pelayanan	Nirwana et al (Nirwana et al., 2024)	Indonesia	Quantitative	Questionnaire	SPSS
25	2024	Stakeholde Conflict Resolution Mechanism in The Process of Acceleration of Tecnological Development and	Khomenko et al (Sustainability & Practices, 2024)	Ukraine	Qualitative	Unidentified	Unidentified

(Source: Figure are author's own work)

3. RESEARCH METHODS

, This study adopts a systematic literature review approach. Unlike a narrative review, this study used the SLR (Systematic Literature Review) approach to analyze relevant literature. The SLR follows a scientific, clear, and repeatable process. It helps organize and categorize key findings in the research area, highlighting gaps or unknown aspects to guide future research directions(Di Vaio et al., 2024).

Articles were selected based on relevance to digitalization in the oil and gas industry, particularly gas stations. A total of 25 studies from peer-reviewed journals, conference proceedings, and industry reports were analyzed, focusing on research methods, regional contexts, and technological applications.

The data for this study were gathered through a content analysis of articles on Oil and Gas industry. These articles were sourced from Google Scholar. Articles focusing on gas station digitalization integration were collected from each journal. Only articles published online between 2016 and 2024 were included in the analysis. Out of the hundreds of articles reviewed, 25 specifically addressed gas station digitalization integration, and all of them were analyzed in this study.

This study followed clear research steps: a) identifying, reviewing, and qualification relevant publications, and b) conducting a bibliometric analysis of the selected papers. The figure outlines the data collection and analysis process used at each stage to a reliable approach.

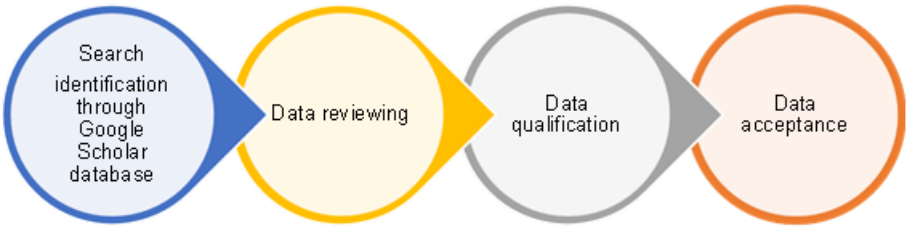

Figure 1. Data Collection and Analysis Process
(Source: Figure are author's own work)

4. RESULTS AND DISCUSSION

This study reflect a diverse range of research focusing on digital transformation in fuel station operations and related industries across various countries. Research methodologies include qualitative, quantitative, and mixed-method approaches, with data collection methods such as questionnaires, observations, and content analysis, etc. To simplify understanding, the following figures cluster the data by methodology, region, analyzing data tools and year of publication focus.

Studies by Methodology

The predominance of **qualitative studies** (19 out of 25) reflects the exploratory nature of digitalization research in the gas station industry. These studies often use case studies, interviews, and observations, allowing researchers to capture nuanced insights about the challenges and potential of digitalization. Examples include: Studies in China using observation and semi-structured questionnaires to analyze service experience and technological integration. Research in Indonesia leveraging NVivo software to systematize reviews of public-private partnerships in digitalization.

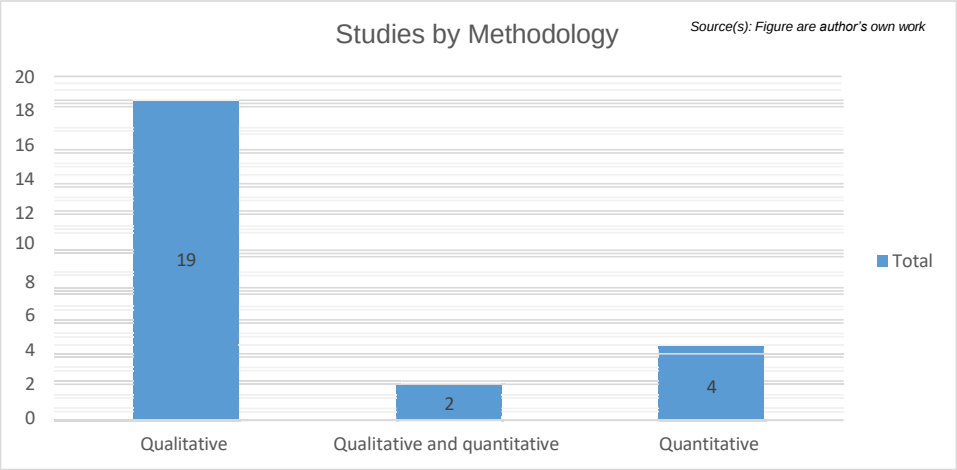

Figure 2. Clustered Data by Methodology
(Source: Figure are author's own work)

Quantitative methodologies (4 studies) were applied primarily to assess customer satisfaction or operational outcomes through surveys and regression analysis. For example: A study from Dubai used regression analysis to evaluate customer satisfaction with modernized services in gas stations. Indonesian research applied SPSS and multiple linear regression to analyze digitalization's impact on consumer satisfaction.

The **mixed-methods approach** (2 studies) aimed to bridge the depth of qualitative data with the generalizability of quantitative findings. These were particularly used in contexts like strategic investment analysis in Indonesia, which combined qualitative frameworks with quantitative models for comprehensive insights.

Studies by Country

Indonesia leads with 8 studies, indicating significant research interest and activity in digital transformation within the local gas station industry. China follows with 4 studies, reflecting the country's emphasis on technological advancements like IoT and big data in energy sectors. Other countries such as Iraq and Russia contributed 2 studies each, while nations like Nigeria, Canada, and Romania had one study each.

The prevalence of Indonesian studies underscores the region's dynamic approach to digitalization, possibly driven by the government's focus on modernizing fuel station operations. In contrast, countries with fewer studies might have less focus on academic exploration in this niche or rely on industry-driven rather than academic documentation.

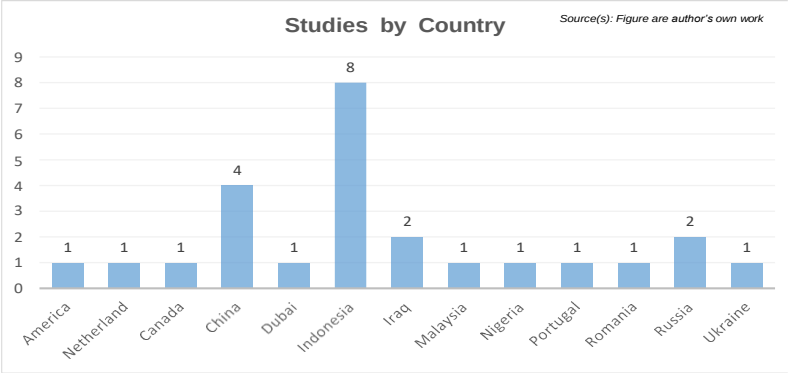

Figure 3. Clustered Data by Country
(Source: Figure are author's own work)

Indonesia's dominance in the dataset (9 studies) indicates an active research agenda aligned with the country's strategic initiatives in digital transformation and public- private partnerships, particularly concerning PT Pertamina. Key topics explored include digital payment systems and public-private partnerships for optimizing digital services.

China (4 studies) reflects the nation's global leadership in IoT and big data technologies. Examples include: A focus on digital twin technologies and smart meters for process optimization. Exploration of service experiences at digitally enhanced gas stations.

Countries with fewer studies (e.g., Nigeria, Canada, and Romania) highlight localized interest in digital transformation. These studies often focus on specific challenges, such a Nigeria's review of digitalized petrol station management systems, Canada's data analysis for IoT systems in gas station convenience stores.

Analyzing Data Tools

The most common approach was labeled simply as "analyzing" (8 studies), reflecting: A focus on observational and descriptive methodologies without specialized tools and this trend suggests that many researchers relied on conceptual frameworks or manual interpretations rather than advanced software. Meanwhile, role of specialized tools such as NVivo Software Used in Indonesia and China for organizing and interpreting qualitative data, especially in studies that involve textual content from interviews and articles. Its use highlights a gradual adoption of technology-assisted qualitative analysis, particularly in systematic reviews. Regression Analysis and SPSS were pivotal in quantitative studies examining customer satisfaction and the impacts of digitalization. For example, SPSS was applied in Indonesia for multiple linear regression, while regression analysis in Dubai evaluated modernization's effect on customer satisfaction.

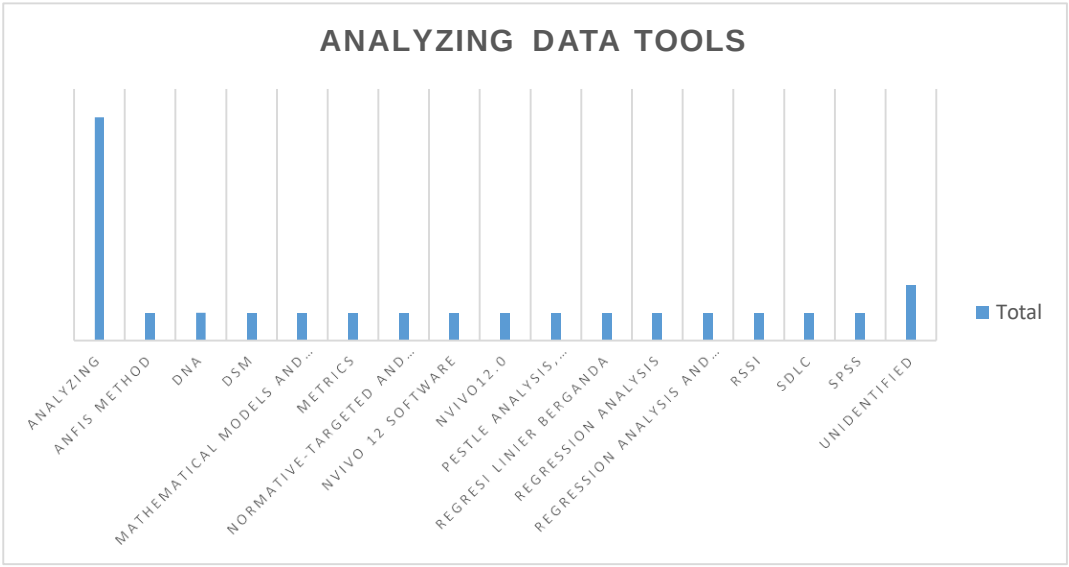

Figure 4. Clustered Data by Analyzing Tools
(Source: Figure are author's own work)

For mathematical models/algorithms were used in China for big data analytics and IoT-based operational optimization. They represent the most technologically advanced techniques in this dataset, paving the way for scalable and precision-driven results. For underexplored tools such as SERVQUAL, PESTLE Analysis, and DNA were employed in isolated studies but demonstrate unique applications, such as SERVQUAL for

measuring service quality in fuel stations, PESTLE Analysis for incorporating macro-environmental factors in strategic planning, DNA for analyzing consumer engagement and sentiment using textual data. These tools, though underused, offer significant potential for niche research areas. Lastly, A small proportion of studies (2) lacked details about their analysis tools. This might indicate either insufficient documentation or reliance on informal methodologies. Ensuring transparency in tool selection and usage is crucial for replicability.

Year of Publication

During period 2016 to 2018, research activity was minimal, with just one study per year. Topics were foundational, focusing on general advantages of digitalization (e.g., the Nigerian petrol station management system) and emerging IoT technologies.

In 2019, A significant jump occurred, with 4 studies published, covering diverse topics like mobile digital payment systems (Indonesia), digital economy modernization in energy (Russia), public service digitalization (Portugal).

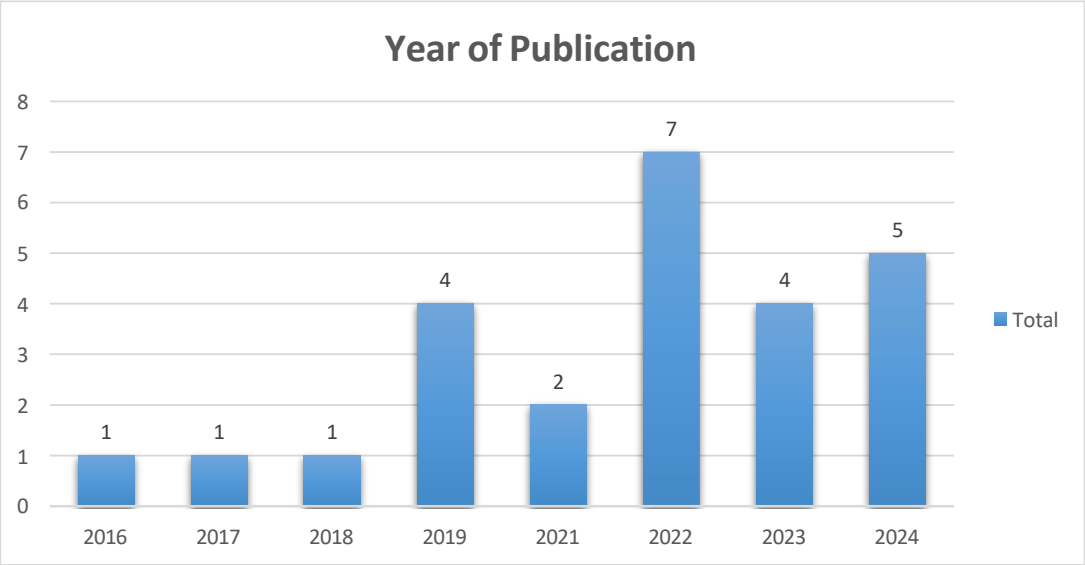

Figure 5. Clustered Data by Year of Publication
(Source: Figure are author's own work)

Meanwhile, during 2021 to 2022 possibly driven by the urgency to adopt digital solutions following the disruptions caused by the COVID-19 pandemic. The highest activity year, with 9 studies published. This surge reflects the consolidation of research efforts, including advanced quality assessment tools (e.g., SERVQUAL), strategic shifts in fuel retail networks (e.g., Romania and Malaysia), technologies such as NVivo software and big data analytics were also prominent. Due to 2023 to 2024, with 9 studies published, the focus has shifted toward advanced technologies and their implications for customer satisfaction, operational effectiveness, and stakeholder conflict resolution. This trend highlights the growing importance of practical applications and innovations like digital twin technology and big data analytics.

DISCUSSION

Digitalization has a significant impact on operational effectiveness at SPBU. Technologies like IoT and big data enable real-time monitoring, predictive maintenance, and streamlined workflows. Digital payment systems improve customer convenience, leading to increased satisfaction and loyalty. However, the lack of research in certain regions and limited quantitative analysis hinder comprehensive understanding and

scalability of findings.

Digitalization has proven to be a game-changer for SPBU, transforming various aspects of their operations. However, several factors need deeper consideration to fully realize its potential:

1. **Enhancing Efficiency Through IoT and Big Data.**

The adoption of IoT devices allows real-time monitoring of fuel levels, equipment performance, and customer traffic. Emphasize how predictive maintenance minimizes downtime and reduces operational costs (Amanda et al., 2024). Big data analytics can optimize supply chains, predict fuel demand, and streamline logistics, ultimately improving operational efficiency.

2. **Improving Customer Satisfaction with Digital Services.**

Digital payment systems and automated services simplify transactions and enhance customer convenience, as noted by (Gumelar et al., 2023). Customized customer experiences powered by data-driven insights can enhance brand loyalty and encourage repeat purchases.

3. **Ensuring Safety with Advanced Technologies.**

(Jia et al., 2024) highlights the potential of digital twin technology in safety management, enabling proactive identification of risks. Automated monitoring systems help maintain compliance with industry safety standards, reducing human error and incidents.

4. **Addressing Regional Disparities.**

Most studies focus on developed regions or major economies such as Indonesia, the USA, and China. Research on underrepresented areas like Africa and South America could uncover unique challenges and opportunities for digitalization. Adapting technological solutions to suit specific regional contexts can improve their efficiency and encourage greater adoption.

5. **Developing Standardized Operational Metrics.**

The lack of standardized frameworks to measure operational effectiveness poses challenges for benchmarking and comparative studies. Future research should focus on creating universal metrics that capture key aspects such as efficiency, customer satisfaction, and safety.

6. **Balancing Qualitative and Quantitative Approaches:**

While qualitative studies provide valuable insights, quantitative analyses are essential for generalizing findings and establishing causal relationships. Integrating both approaches can offer a more comprehensive understanding.

By addressing these factors, SPBU operators and policymakers can maximize the benefits of digitalization, ensuring sustainable and efficient operations

CONCLUSION

This systematic literature review highlights the diverse approaches and methodologies employed to explore the digitalization of gas stations and related energy services. The research demonstrates significant progress in adopting digital tools and systems to enhance operational efficiency, customer satisfaction, and service quality. Key findings include the role of advanced technologies such as IoT, big data, and digital twin systems in revolutionizing service delivery and operational optimization. Studies also emphasize the importance of integrating user-focused innovations like mobile payment systems and e-participation platforms to align with contemporary consumer expectations.

This review highlights the transformative potential of digitalization in SPBU operations while identifying critical gaps in research. Future studies should address these gaps by incorporating quantitative methods and exploring underrepresented regions. Developing standardized metrics for operational effectiveness is essential for benchmarking and comparative analysis.

Despite these advancements, challenges persist, particularly in the areas of stakeholder collaboration, regulatory compliance, and the equitable distribution of technological benefits. Future research should address these gaps while exploring emerging technologies and sustainable practices to drive holistic digital transformation in the energy sector.

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