Proceedings of the 3rd International Conference on Business and Policy Studies
DOI: 10.54254/2754-1169/67/20241323

Current Status and Future Outlook of Pipeline Transportation Since the COVID-19

Junfei Qu[1,a,*]

[1]*SWUFE-UD Institute of Data Science, Southwestern University of Finance and Economics, chengdu, sichuan 611030, China*
a. qq1109532608@163.com
**corresponding author*

Abstract: Pipeline transportation is an important logistics method widely used in the energy industry and other fields. With the global economic development and increasing energy demands, the demand for pipeline transportation has been growing. This study aims to explore the application areas of pipeline transportation and investigate the recent innovations in technology and pricing strategies. Additionally, it provides new solutions to the challenges faced in international logistics during the COVID-19 pandemic by highlighting the advantages of pipeline transportation. Through a literature review approach, this paper summarizes relevant research, including recent technological advancements, new pricing models, and the advantages of pipeline transportation in recent years. Lastly, this paper provides an overview of areas that still require improvement in this study, for the benefit of future research needs.

Keywords: pipeline transportation, pricing model, monitoring, advantages

1. Introduction

At present, with the continuous advancement of modernization and technology, the field of research on pipeline transportation applications has attracted considerable attention. Pipeline transportation is a crucial component of the energy sector and various industries, which has led to a significant amount of research activity in this area. Recent studies have primarily focused on three main areas: automation of pipeline operations, improvement of safety measures, and innovation in pricing strategies. These research efforts aim to enhance the efficiency, safety, and economic viability of pipeline transportation systems. One example of such research is the work conducted by Li Jing, who has explored pipeline defect detection methods based on ultrasonic guided waves and machine vision. This research builds upon commonly used techniques in the field and aims to obtain a more intuitive understanding of pipeline defects [1]. By leveraging ultrasonic guided waves, it becomes possible to analyze the propagation of sound waves within the pipeline and identify any potential defects or anomalies. Integrating machine vision techniques further enhances the accuracy and efficiency of defect detection, providing valuable information for maintenance and repair activities. While these investigations have contributed substantially, there is a gap in conducting a comprehensive overview of the applications of this field, thus setting the stage for the research.

The study adopts a systematic and in-depth review method, analyzing a range of scientific literature to provide an overarching examination of the pipeline transportation's contemporary applications.

The significance of this review is manifold. It contributes to the growing area of research by providing an in-depth yet broad-brush consolidation of knowledge on pipeline transportation applications, which is a much-needed effort in today’s rapidly evolving landscape. Moreover, the paper gives practical insights for industry practitioners, underscoring the merits and demerits of various methods and identifying areas for further research. More importantly, it feeds into a macroscopic understanding of pipeline transportation's role and its scope for further development and innovation, prompting more research activity.

2. Principles and Current Development Status

Oil and gas pipeline engineering systems are complex and serve as the foundation for national economic development and ensuring the livelihood of citizens. Unlike other transportation, pipeline transportation is characterized by large diameters, long-distance conveyance, high operating pressures, large oil (gas) volumes, and the convenience of continuous operation throughout the year. It is primarily used for transporting long-distance liquid and gas cargo, navigating through different terrains and geological structures underground [2]. Pipeline transportation has seen significant development in its pricing strategy and technological advancements.

2.1. Pricing Strategy

In terms of the current research, fixed costs comprise a significant portion of the total cost of pipeline transportation. To ensure economic efficiency, it is necessary to achieve a certain level of total pipeline volume to spread out the fixed costs. Transport companies have to pay leasing fees to acquire equipment usage rights. Variable costs include power costs, which vary based on factors such as transport volume and pipeline diameter. The cost of larger pipelines is significantly lower than that of smaller pipelines, and economies of scale decrease as the overall product volume increases [3].

In terms of pricing, there has been new research on the Two-part system mechanism for natural gas pipeline transportation, which has led to the design of a "dual-level pricing model for pipeline transportation." In the traditional single-level program, the pipeline usage fee is only based on the actual volume of gas transported. However, in the two-level program, in addition to the usage fee, a pipeline capacity fee is introduced to recover the fixed costs associated with the pipeline's transportation capacity. This pricing approach is considered fairer in ensuring the benefits of various participants in the pipeline transportation market.

Moreover, the two-level program model allocates the fixed costs reasonably between the pipeline capacity fee and the usage fee. This not only addresses the issue of reasonable profits for pipeline transportation companies but also encourages users to pre-order the transportation capacity based on more accurate gas consumption to avoid losses. As a result, it helps improve the utilization rate of the pipeline network.

Two-level program model is a decision model commonly used in product pricing research. In this model, the upper-level and lower-level decision-makers control distinct sets of decision variables and pursue their respective objective functions. The upper-level decisions influence the behavior of the lower-level by setting decision variables and granting some degree of autonomy within certain boundaries. The lower-level decision variables are typically a function of the upper-level decision variables. Ultimately, the following model is formulated [4]:

Upper-level planning model:

DOI: 10.54254/2754-1169/67/20241323

$$\max U=\max[(P_uQ_c+P_vQ_d+P_rQ_r+\omega Q_c) \\ -(c_0+c_1Q_c)+\textstyle\sum_{i=1}^{4}V_i\,q_i-N] \\ \text{S.T.}\begin{cases}0\leqslant\sum_{i=1}^{4}q_i\leqslant Q_c\\ 0\leqslant\omega Q_c\leqslant S'\end{cases} \tag{1}$$

Lower-level planning model:

$$\max\pi=\max[(P_uQ_c+P_vQ_d+P_rQ_r+\omega Q_c)-(c_0+c_1Q_c)] \\ \text{S.T.}\begin{cases}0\leqslant Q_c\leqslant Q_d\leqslant Q_c'\\ 0\leqslant Q_r\leqslant Q_r'\\ 0\leqslant P_u\leqslant P_u'\\ 0\leqslant P_v\leqslant P_v'\\ 0\leqslant P_r\leqslant P_r'\\ a\leqslant(P_uQ_c+P_vQ_d+P_rQ_r+\omega Q_c)\\ -(c_0+c_1Q_d)\leqslant b\end{cases} \tag{2}$$

Through simulation calculations,the promotion effect of "two-part system" pricing on overall social benefits is significant and has more advantages compared to traditional pricing.

2.2. Technological Advancements

In recent years, technological developments related to pipeline transportation have primarily focused on pipeline safety monitoring and management.

Pipeline safety is an unavoidable concern in the transportation of oil and gas due to factors such as pipeline pressure, construction damage, punctures for oil theft, and corrosion [5]. Leakage issues in pipelines can lead to a series of safety problems. To address this issue, research on detecting leaks in oil and gas pipelines began as early as the 1970s. The current research field is divided into three main categories: manual inspection, hardware, and software. Hardware-based detection methods primarily include infrared sensors, odor sensors, acoustic sensors, optical fibers, and negative pressure waves. These sensor devices are used based on physical principles to detect and locate pipeline leaks. On the other hand, software-based detection relies on data collection through computer platforms to acquire various signals, which are then analyzed to identify and locate pipeline leaks [6]. Currently, with the increasingly widespread use of pipeline transportation, there is a growing demand for improved effectiveness and precision in pipeline leak detection and localization. While most methods can detect leaks in more severe cases, accurately detecting and locating minor leaks remains a challenge. Moreover, various methods of pipeline leak detection have their own limitations and drawbacks. Therefore, combining multiple methods has become a major topic in recent years.

Recent studies have blurred the boundaries between hardware and software monitoring, employing a combination of multiple methods for monitoring. For example, Wei He and his team designed a pipeline monitoring system based on the OpenHarmony platform, utilizing the monitoring principle of negative pressure waves. This system demonstrated higher development efficiency compared to other monitoring systems [7]. Another group of researchers has integrated advanced technologies such as neural networks and artificial intelligence into leak detection systems, promoting the development of hybrid intelligent leak detection technologies. Jun Li and his team, for instance, proposed a signal feature extraction technique based on the Hilbert-Huang Transform and Empirical Mode Decomposition (EMD-HHT) using a BP neural network and distributed fiber optic detection method, effectively reducing the influence of noise on monitoring accuracy [8].

On the other hand, some researchers have focused on incorporating automation equipment into pipeline transportation management. For example, Yubiao Wan discussed the application of PLC systems in automating oil and gas pipeline transportation. This enables remote monitoring of the transportation process, resulting in better system supervision and control, ultimately reducing the occurrence of risks [9]. Haijun Ye and his team developed an automated control system for oil and gas pipeline process equipment based on PID control principles, various sensors, and the TinyOS operating system. This system effectively detects the transportation status of petroleum pipelines, thus preventing pipeline accidents [10].

2.3. Future Prospects

With the increasingly widespread application of pipeline transportation, errors and omissions are inevitable in the process of its application. Therefore, the following recommendations are proposed for the future development of this field:

2.3.1. Promote the Application of Automation and Intelligence in Pipeline Transportation

The application of automation and intelligence in pipeline transportation can achieve autonomous operation and remote monitoring of pipeline equipment. By using artificial intelligence, machine learning, and automatic control technology, the pipeline transportation system can automatically execute operational tasks, reducing the need for human intervention. Automation systems can collect real-time data through sensors and monitoring devices to monitor and control the transportation process. This can improve transportation efficiency, reduce human errors, and provide higher levels of safety.

At the same time, automation and intelligence technologies also provide better decision support for pipeline transportation. By collecting a large amount of transportation data and conducting real-time analysis, more accurate transportation predictions and optimization solutions can be obtained. Intelligent algorithms can learn and adjust based on real-time and historical data, thereby improving transportation effectiveness. These technologies can help transportation managers make wiser decisions, optimize resource allocation and transportation routes, and improve the overall efficiency of the pipeline transportation system.

2.3.2. Promote the Development of Big Data Analytics Methods in Pipeline Transportation

The application of big data analytics in pipeline transportation can help discover hidden patterns and trends, optimizing the pipeline transportation process. The vast amount of data generated by pipeline transportation can include transportation parameters, equipment states, environmental conditions, and other information. By using big data analytics techniques, these data can be integrated, processed, and analyzed, revealing potential correlations and patterns. This helps accurately predict maintenance requirements of pipeline equipment, take timely repair and maintenance measures, and improve equipment reliability and lifespan.

In addition, big data and analytics techniques can also be used for pipeline safety monitoring and risk assessment. By analyzing safety-related data, potential risk points and hazards can be identified promptly, leading to the implementation of appropriate preventive measures. Big data analytics can also be used to establish safety models and warning systems, enabling real-time monitoring of pipeline transportation processes and rapid response to any abnormal situations.

DOI: 10.54254/2754-1169/67/20241323

3. Advantages and Application

Pipeline transportation has significant advantages, especially in the backdrop of unforeseen events like the COVID-19 pandemic, where many energy companies have faced tremendous impacts. Wang Jiahui and Wang Guodong proposed that the cost of pipeline transportation for oil is less than 15% per kilometer compared to the cost-effective railway transportation [11]. Additionally, Zhang Jihai, Xiao Tian, and Li Ting noted that pipeline transportation has advantages compared to other modes of transportation, including high reliability, minimal permanent land occupation, strong resilience to risks, and low energy consumption and losses [12]. Besides, Cui Jing suggested that the distribution of finished oil pipelines exhibits a characteristic of multiple points and long lines [13]. In other energy sectors, pipeline transportation still enjoys unique advantages. Xu dong et al. indicated that in the transportation of carbon dioxide, pipeline transportation possesses strong continuity, high safety, large transportation capacity, low operating costs, predominantly underground pipelines, saving land resources, unaffected by weather conditions, minimal CO_2 leakage, and minimal environmental pollution [14]. Based on this feature, pipeline transportation has a more significant advantage in current international transportation.

Currently, many studies on pipeline transportation mainly focus on its advantages without considering the research in the background of the COVID-19. This transportation method can help many energy companies address numerous economic issues, since the logistics cost of finished oil accounts for over 80% of the overall logistics cost, which is the main factor determining logistics efficiency and cost [15]. For instance, on April 21, 2020, the May futures contract for benchmark U.S. light crude oil, commonly known as WTI, not only reached a historic low but also unprecedentedly closed at a negative value, with a settlement price of -$37.63 per barrel. According to Wang Tianjiao, Li Qiang and Zhu Jihong, oil companies such as Schlumberger, Halliburton, National Oilwell Varco, and Tenaris have resorted to various measures to prevent bankruptcy. However, these debt crises can be alleviated by transitioning a portion of oil and gas transportation by road and waterways to pipeline transportation [16].

Additionally, in the background of the COVID-19, pipeline transportation can further deepen the construction of the Belt and Road Initiative. Ebergen and Guo Yun has been pointed out that as of the end of June 2019, the China-Kazakhstan crude oil transportation pipeline had cumulatively delivered 126 million tons of crude oil to China. At the same time, by 2017, the total transportation capacity of the China-Kazakhstan natural gas pipeline had reached 55 billion cubic meters [17]. In the current situation where other modes of transportation are somewhat impacted by the pandemic, pipeline transportation plays a significant advantage.

4. Conclusions

With the emergence of new technologies and the application of artificial intelligence in the field of pipeline transportation, the monitoring and maintenance of pipeline transportation have become more intelligent and precise. At the same time, the introduction of new models and methods has made pricing in pipeline transportation more flexible and fairer. Furthermore, pipeline transportation has certain advantages in dealing with the challenges of international logistics during the COVID-19 pandemic due to its low energy consumption and large capacity. Additionally, the inherent closed nature of pipeline transportation reduces the possibility of personnel contact and handling of goods, thus reducing the risk of transmission. It has played a significant role during the pandemic. Moreover, pipeline transportation is characterized by stability and predictability, making it suitable for long-term reliable energy supply. Despite the comprehensive review and analysis of pipeline transportation, there are a few limitations in this study. Firstly, it heavily relies on literature review methods and lacks primary data collection or field surveys, which may result in a limited understanding of realworld situations. Therefore, future studies can employ empirical research methods, such as conducting on-site surveys and collecting actual data, to obtain more specific and comprehensive results. Furthermore, although this study briefly mentions the challenges and issues faced by pipeline transportation, it does not delve into potential solutions. Future research can focus on addressing the problems encountered in pipeline transportation and propose corresponding solutions. For example, studying new pipeline technologies, improving pipeline materials, and optimizing transportation networks can enhance the efficiency and safety of pipeline transportation.

References

[1] *Li, J. (2023). Pipeline Defect Detection Based on Ultrasonic Guided Wave and Machine Vision (Master's thesis, Inner Mongolia University of Science and Technology).*
[2] *Liu, J. (2014). Operation characteristics and common accidents of oil and gas pipelines. China Petroleum and Chemical Standard and Quality(09), 267.*
[3] *Liu, X. (2022). Financial cost analysis and forecasting of bulk cargo transportation enterprises. China Storage & Transport (09), 56-58.*
[4] *Zheng, X., Wang, J., & Ning, M. (2022). "Two-Part System" Pricing Mechanism Research Based on Two-Level Programming Model. Petroleum And New Energy (05),68-75.*
[5] *Zhou, J., Yang, F., An, L., Wang, Z., & Li, B. (2022). Research on Oil and Gas Pipeline Leakage and Storage and Transportation Technology. Chemical Enterprise Management (21), 80-83.*
[6] *Yuan, M., Gao, H., Lu, J., Yang, D., & Hou, Y. (2022). Overview of Leakage Detection Technology for Oil and Gas Pipelines. Journal of Jilin University (Information Science Edition) (02), 159-173. doi:10.19292/j.cnki.jdxxp.20220411.003.*
[7] *He, W., et al. (2023). Design of Pipeline Leak Monitoring System Based on OpenHarmony. Petro & Chemical Equipment 26.07(2023): 52-56.*
[8] *Li, J., Zhang, W., Gao, Z., Yao, R., Zhang, J., & Zhang, D. (2023). Monitoring technology of third-party damage events in long-distance natural gas pipeline located by EMD-HHT. Journal of Safety Science and Technology (03), 121-129.*
[9] *Wan, Y. (2022). Application of PLC in Natural Gas Pipeline Automation Transportation. China Petroleum and Chemical Standard and Quality (21), 89-91.*
[10] *Ye, H., Zhu, S., Liu, Y., & Song, Z. (2023). Discussion on automatic control of process equipment for long-distance oil and gas pipelines. Petrochemical Industry Technology (04), 153-155.*
[11] *Wang, J., & Wang, G. (2022). Ensuring the safety of oil pipeline transportation under new circumstances. Shandong Chemical Industry (09), 195-196. doi:10.19319/j.cnki.issn.1008-021x.2022.09.057.*
[12] *Zhang, J., Xiao, T., & Li, T. (2011). Status and problems and suggestions of China's oil supply. Energy of China (10), 5-9+25.*
[13] *Cui, J. (2023). Fixed Asset Management of Finished Oil Pipeline Transportation Enterprises under New Situation. Occupational Circle (07), 40-42.*
[14] *Xu, D., Liu, J., Wang, L., Wei, N., Gao, T., Yang, Y., & Chen, H. (2021). Technical and economic analysis on CO2 transportation link in CCUS. International Petroleum Economics (06), 8-16.*
[15] *Lu, Z., & Gao, P. (2016). PetroChina's Primary Oil Product Logistics Today, Challenges and Solutions. Sino-Global Energy(05), 14-20.*
[16] *Wang, T., Li, Q., & Zhu, J. (2020). Black swans come one after another, and international oil service companies struggle to support. Sinopec Monthly (05), 83-85.*
[17] *Ai, B., & Guo, Y. (2020). Research on Energy Transportation between China and Kazakhstan from the Perspective of the Belt and Road. Logistics Sci-Tech (01), 133-135.*