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Condition of Existing Gas Pipeline Systems in Uzbekistan

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Annotation
Uzbekistan possesses one of the largest and most extensive gas pipeline systems in Central Asia, with more than 90,000 km of networks supplying households, industries, and serving as a regional transit hub. However, the system faces critical challenges due to aging infrastructure and outdated equipment. Nearly half of the pipelines have been in service for more than 30 years, significantly increasing the risks of leaks, ruptures, and ecological impacts. Methane emissions from deteriorating steel pipelines pose a major environmental concern, while corrosion and valve failures account for nearly one-third of all accidents. International experiences show that the absence of transparent safety statistics weakens public trust and can lead to restrictive regulations. This study emphasizes the importance of adopting modern risk assessment methods, transparent reporting, and the introduction of polymer materials and trenchless reconstruction technologies. These measures are essential for ensuring safe, reliable, and environmentally sustainable operation of Uzbekistan's gas pipeline system.

Keywords: Gas pipeline system, infrastructure aging, methane emissions, ecological risks, corrosion damage, pressure categories, safety performance, modernization technologies, trenchless reconstruction, energy security.

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Introduction

The gas pipeline system of Uzbekistan is one of the most extensive infrastructures in Central Asia, covering all regions of the country and connecting to the transnational gas transport network [1]. With more than 90,000 km of pipelines of varying pressure classes, the system plays a central role in meeting the domestic demand for natural gas while also serving as a transit hub within the region. Historically, Uzbekistan has been a major gas supplier, with the Bukhara gas fields providing fuel not only to national consumers but also to neighboring countries [2, 3]. However, the reliability and safety of these networks are increasingly under question due to the high proportion of aging infrastructure [4].

Globally, the natural gas industry faces rising concerns regarding environmental and technological safety. In densely populated areas, expansion of distribution systems is often contested by public opinion and constrained by stricter safety legislation. Similar challenges are emerging in Uzbekistan, where outdated steel pipelines and worn-out equipment create elevated risks of leakage, rupture, and accidental failures [5, 6]. Such risks are further amplified by the absence of regular international-level statistical reporting on incidents, which complicates transparent risk communication and undermines public trust.

Safety statistics collected by international associations, such as the European Gas Incident Data Group (EGIG), highlight the importance of structured data collection for understanding risks in transmission and distribution systems. However, in Uzbekistan, official data on gas pipeline safety remain fragmented [7]. This limits the ability to conduct systematic risk assessments and implement preventive measures based on evidence. The lack of reliable and accessible information also creates opportunities for unrealistic risk scenarios to influence policy, threatening the economic viability of the gas industry.

From an ecological perspective, the aging of Uzbekistan's gas pipeline system has implications beyond technological reliability [8, 9]. Methane leakage, corrosion-induced failures, and emergency repairs contribute to greenhouse gas emissions and localized environmental damage. In addition, the increasing share of pipelines exceeding 30 years in service raises concerns about their continued compliance with safety and environmental standards. Without systematic modernization, these pipelines may become critical sources of ecological and social risk [10].

The socioeconomic importance of Uzbekistan's gas transport network cannot be overstated. More than 80% of households rely on low-pressure pipelines for daily gas consumption, while industrial enterprises depend on medium- and high-pressure networks [11]. Interruptions or failures in these systems can disrupt entire sectors of the economy, affecting both energy security and public welfare. Therefore, ensuring the integrity and modernization of the pipeline system is not only a technical issue but also a matter of national security and sustainable development.

In this context, the present study evaluates the condition of Uzbekistan's gas pipeline system by analyzing service life, distribution by pressure category, and associated risks. By comparing the current state with international safety practices, the study identifies key shortcomings and outlines directions for technical modernization and ecological risk mitigation.

Materials and methods

The research methodology was based on a comprehensive analysis of technical, organizational, and environmental aspects of Uzbekistan's gas transport system. Primary data were drawn from national statistical reports, regulatory documents, and technical passports of gas pipelines, which provide information on length, age distribution, and operational conditions. Supplementary data were obtained from international sources, such as the European Gas Incident Data Group (EGIG), to compare Uzbekistan's situation with global safety benchmarks.

Pipeline classification was carried out according to pressure categories: high-pressure, medium-pressure, and low-pressure systems. Within each category, pipelines were further divided by service life into three groups: up to 10 years, 10–20 years, and over 20–30 years. This approach made it possible to identify the proportion of aging infrastructure and evaluate its implications for reliability and safety. The length of pipelines within each group was calculated in kilometers, and the total operational extent of the network was assessed.

To assess safety risks, the study applied a risk analysis framework that combined incident frequency, potential consequences, and ecological impact. Data on accidents, failures, and gas leakages were examined to identify trends and recurring technical problems. Special attention was given to corrosion-related damage and the wear of steel pipelines, which represent the most

frequent causes of accidents in the Uzbek gas network. Risk assessment was complemented by ecological analysis, focusing on methane emissions and potential impacts on soil, water, and air quality.

Finally, the research methodology included a comparative evaluation of modernization approaches. Techniques such as polymer pipeline replacement and trenchless reconstruction methods were analyzed for their economic and ecological benefits. The evaluation emphasized their applicability to Uzbekistan's conditions and potential to reduce the proportion of outdated pipelines. This integrated methodological framework ensured a balanced analysis that accounted for both technical safety and ecological sustainability of the gas pipeline system.

Results

The gas transport system of Uzbekistan covers all regions of the republic and has connections to the international gas transport network. Recent studies on gas transport risk assessment have identified potentially hazardous zones that may form as a result of high-pressure pipeline ruptures. These studies established transportation distances under varying pressure conditions, emphasizing the complexity of maintaining safety in long-distance transmission.

In many countries, particularly in urban areas, the development of the gas industry faces challenges related to declining public acceptance and increasing safety requirements. The lack of statistically verified data on distribution safety has led authorities and opinion leaders in some countries to question the safety of gas and adopt laws based on simplified debates or unrealistic scenarios. Similar trends have been observed in Europe, where, for example, Switzerland once considered prohibiting the construction of new gas distribution lines in densely populated regions. Such approaches, based on non-scientific attribution of risk classes rather than empirical safety statistics, pose a threat to the economic viability of the gas sector.

In terms of safety, reliable statistics on accidents and incidents are critical. While international reports such as the EGIG (European Gas Incident Data Group) provide information on transport-related incidents across continents, there has historically been a lack of regularly published international data on accidents in the distribution and end-use sector. This absence of systematic reporting has weakened the industry's ability to communicate risks effectively and maintain public trust. In recent years, however, greater efforts have been made to improve communication by translating statistical data into Safety Performance Indicators (SPI).

The Uzbek gas pipeline system is among the most developed in the region, with a total length of 90,328.4 km. Of this, 9,123.4 km are high-pressure pipelines, 22,175.8 km are medium-pressure, and 59,029.4 km are low-pressure. A significant share of this infrastructure is aging: 44,294.5 km have been in service for over 30 years, 25,774.5 km for up to 30 years, and only 20,259.4 km for less than 10 years. For example, the Bukhara gas field served as the starting point for the Central Asian gas network, supplying gas to the Russian Federation 50–60 years ago. Currently, the system includes 393 gas distribution stations and 25 compressor stations operating with 250 units, ensuring delivery from production to consumers (Table 1).

Table 1. Service life distribution of pipelines by pressure class (km)

Service life	High-pressure (km)	Medium-pressure (km)	Low-pressure (km)
≤10 years	385.081	773.884	1310.379
10–20 years	302.659	543.586	1503.355
≥20–30 years and above	272.729	458.232	1663.046
Total	**960.469**	**1775.702**	**4476.780**

According to the pipeline passport data, 5,034.5 km are under 10 years old, 5,454.9 km fall into the 10–20 years category, and 4,315.8 km are between 20 and 30 years old (Figure 1). The high

proportion of pipelines exceeding 30 years in service underlines the risks of equipment degradation and increased likelihood of incidents such as gas leakage, valve failures, and corrosion damage. These factors account for nearly one-third of all reported accidents in the system. Without targeted modernization, the share of outdated pipelines will continue to grow, undermining the reliability and ecological safety of the gas transport network.

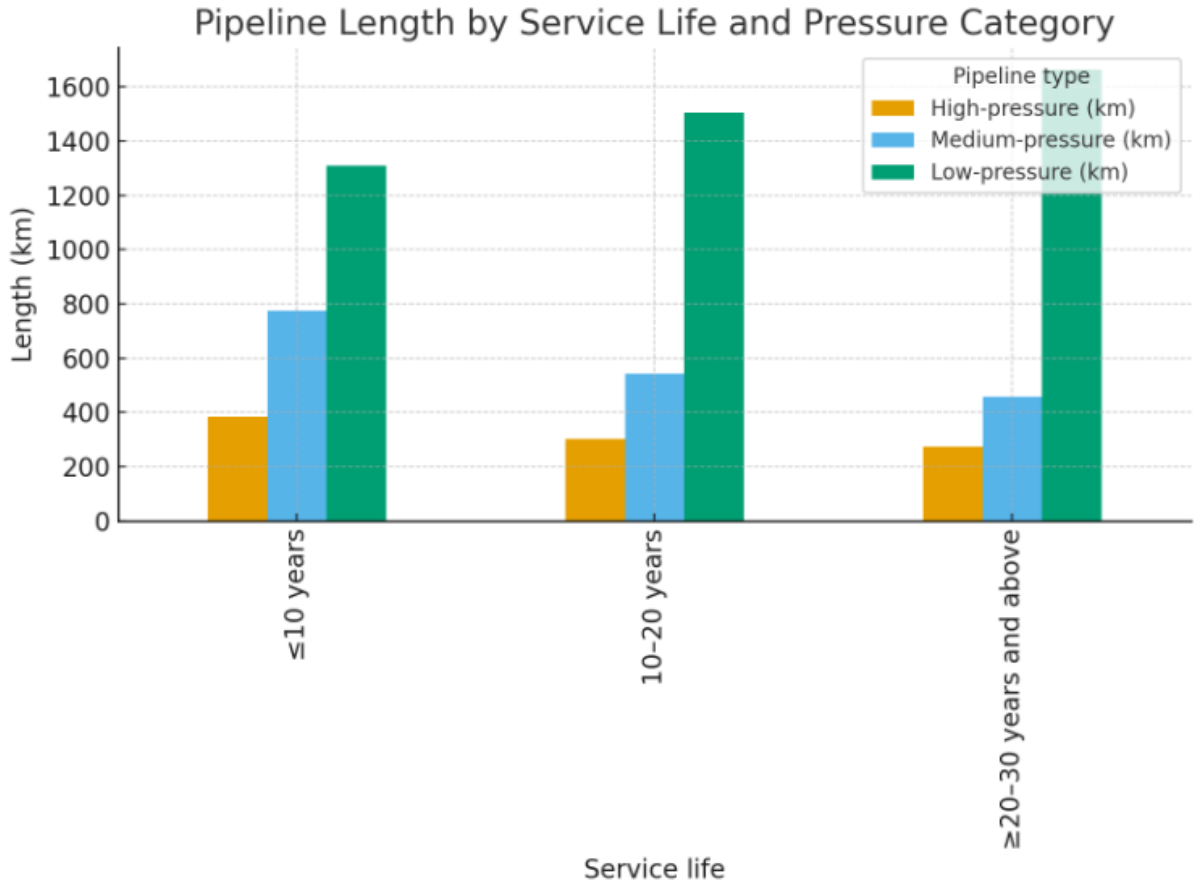

Figure 1. Pipeline length by service life and pressure category

Currently, 80% of the total pipeline length is comprised of low-pressure networks, while medium- and high-pressure pipelines account for 20%. Household consumers mainly use gas supplied through low-pressure pipelines, while medium-pressure pipelines serve both industrial and large household consumers. High-pressure pipelines primarily supply gas to industrial enterprises through distribution stations. This structure emphasizes the critical importance of maintaining safe and reliable operation across all pressure categories, as disruptions could directly affect both household comfort and industrial productivity.

Modernization technologies, including the use of polymer materials and trenchless reconstruction methods, are considered especially beneficial for Uzbekistan. According to projections, 70–80% of total capital investment in the gas supply pipeline system will be directed toward construction and rehabilitation of pipeline infrastructure. These measures are necessary to prevent further deterioration, reduce risks of accidents, and ensure uninterrupted gas supply for both domestic and industrial users.

Discussion

The assessment of Uzbekistan’s gas pipeline system reveals that the network has reached a critical stage of aging, with nearly half of the pipelines operating for more than 30 years. This structural deterioration significantly increases the probability of accidents, including leaks, ruptures, and

valve malfunctions. Given that one-third of all recorded incidents are linked to corrosion and outdated equipment, the ecological and safety risks associated with this infrastructure are considerable. These findings highlight the urgency of modernization efforts to ensure system reliability and reduce environmental hazards.

Methane leakage from deteriorating pipelines is one of the most pressing ecological challenges. As a greenhouse gas with a global warming potential many times greater than carbon dioxide, methane emissions from worn-out pipelines contribute disproportionately to climate change. The absence of systematic ecological monitoring and reporting on methane losses within the Uzbek system compounds this challenge, making it difficult to design effective mitigation measures. Integrating methane quantification into pipeline management would align the country's gas sector with global environmental standards.

Safety perceptions and public trust in the gas industry are also influenced by the availability of reliable statistics. International experiences, particularly in Europe, demonstrate how incomplete or inconsistent reporting can lead to restrictive legislation based on unrealistic scenarios. The Uzbek case underscores the importance of transparent communication using tools such as Safety Performance Indicators (SPI). By adopting a proactive approach to risk reporting, Uzbekistan could strengthen public confidence and avoid policy measures that undermine the economic sustainability of its gas sector.

Economic risks are closely tied to technical and ecological challenges. With 80% of the network composed of low-pressure pipelines serving household consumers, system failures can have widespread social impacts. Interruptions in domestic gas supply directly affect household welfare, while failures in medium- and high-pressure systems pose risks to industrial productivity. These disruptions could trigger broader socio-economic instability, particularly in regions heavily dependent on natural gas. Consequently, modernization and preventive maintenance are not only technical requirements but also essential measures for national energy security.

Finally, modernization technologies offer promising solutions to address these challenges. Trenchless reconstruction methods and polymer pipeline replacements represent cost-effective and environmentally friendly alternatives to traditional steel pipeline repairs. Targeted investment in such technologies could significantly extend the service life of existing systems, reduce accident rates, and lower greenhouse gas emissions. Strategic planning and prioritization of high-risk sections are therefore crucial to ensuring the sustainable future of Uzbekistan's gas pipeline system.

Conclusions

The study of Uzbekistan's gas pipeline system shows that a significant portion of the network is aging, with nearly half of pipelines in service for more than 30 years. This situation poses growing risks of accidents, technical failures, and ecological impacts. The aging infrastructure threatens the reliability of gas supply and highlights the urgent need for systematic modernization.

Methane leakage from deteriorating pipelines represents one of the most critical ecological shortcomings. These emissions contribute to climate change and reduce the efficiency of gas delivery. Without integrating greenhouse gas monitoring into the management of pipeline systems, Uzbekistan's gas sector will continue to face ecological risks that are underestimated in current planning approaches.

The absence of transparent and consistent safety statistics undermines public trust and exposes the industry to restrictive regulations. By adopting international practices such as Safety Performance Indicators, the Uzbek gas sector can better communicate residual risks and demonstrate its commitment to continuous improvement.

The socioeconomic importance of gas pipelines in Uzbekistan, particularly for households dependent on low-pressure networks, underscores the national significance of addressing these issues. System failures would not only disrupt domestic energy supply but also create broader economic and social instability.

Modernization strategies, including the application of polymer materials and trenchless technologies, offer cost-effective and environmentally sustainable solutions. Prioritizing these approaches in national energy planning will help extend the service life of pipelines, reduce accidents, and ensure uninterrupted and safe gas supply to all categories of consumers.

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