Collaborate

Route Selection and Environmental Strategies in Subsea Pipeline Engineering

Part of the Book Series "Maritime Engineering"

Relationship of Pipeline Route to Long Term Integrity

Abstract

The provision of clean water to island regions such as Gusung Island by the Makassar Regional Water Company (PDAM Makassar) requires a complex and high risk seaborne pipeline system. This article examines Scope 8 as the comprehensive management of pipeline assets, encompassing planning, construction, operation, maintenance, and continuous evaluation of system performance. The aim is to identify key risks and analyze factors affecting pipeline integrity. The study results indicate that key risks include corrosion due to the marine environment, headloss, mechanical damage due to waves, currents, and shipping activities, as well as potential leaks due to material fatigue and joint failure, which are also influenced by seabed geotechnical conditions and environmental changes. Pipe integrity is largely determined by the selection of appropriate materials such as HDPE or coated steel, the implementation of protection systems such as coatings and cathodic protection, and the implementation of risk based inspections and regular condition monitoring. With the implementation of integrated and data driven risk management, the seaborne pipeline system can operate more safely, efficiently, and sustainably, thereby supporting the sustainability of clean water distribution in island regions.

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1. Introduction

The availability of clean water in archipelagic regions is a critical issue widely discussed in various studies, particularly on small islands with limited freshwater resources and a heavy reliance on mainland supplies. Previous studies in environmental and marine engineering have shown that a clean water distribution system using submarine pipelines is the most effective and sustainable solution compared to alternative distribution methods, such as transporting water by tanker, which tend to be inefficient and have high operational costs. In the Indonesian context, the implementation of this system has begun to be developed in several coastal and island areas, including by the Makassar Water Company (PDAM) in an effort to meet the clean water needs of the community on Gusung Island [1].

In line with the geographical challenges of the South Sulawesi waters, the Makassar City Water Company (PDAM) is currently striving to improve services to fulfill the basic right to clean water for the community on Gusung Island. However, installing submarine pipelines in Makassar waters is highly technically complex. These waters not only serve as an ecological space, but also serve as a busy maritime transportation route, a port area, and are subject to active seabed dynamics. The

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main challenge in submarine pipeline construction lies not only in the pipe connection process, but also in the long term integrity of the structure. Mistakes in route selection can lead to fatal failures due to environmental factors and human activity. Therefore, a risk management approach is a vital tool that must be implemented from the planning stage. This paper focuses on the argument that pipeline integrity begins with route selection. Determining the right route is not only about distance efficiency, but also an early risk mitigation strategy. Factors such as seabed slope, sedimentation patterns, and navigation hazards from ship traffic around Makassar are determining variables that must be integrated into risk-informed route selection [2].

In addition to environmental considerations, route selection also has significant implications for the long-term operational and maintenance requirements of the pipeline system. A route that passes through areas with stable seabed conditions and minimal external interference can reduce the frequency of inspections, repairs, and emergency interventions throughout the pipeline's service life. Conversely, routes located in areas prone to sediment movement, erosion, or intensive maritime activities may require more frequent monitoring and higher maintenance expenditures. Therefore, evaluating potential risks during the route selection stage can contribute substantially to improving operational efficiency and reducing lifecycle costs [3].

Moreover, advances in marine survey technologies have enabled engineers to conduct more comprehensive route assessments before construction begins. Bathymetric surveys, geotechnical investigations, and hydrodynamic analyses can provide valuable information regarding seabed characteristics, current patterns, and potential hazard zones. By integrating these data into the planning process, decision-makers can identify safer and more sustainable pipeline corridors that support long-term structural integrity. As a result, route selection becomes not only a design consideration but also a strategic element in ensuring the reliability and sustainability of clean water distribution systems for island communities such as Gusung Island [4].

2. Discussion of Main Issues

The clean water crisis on Gusung Island is a fundamental problem directly felt by the community. Limited freshwater resources make it difficult to meet daily needs such as drinking, cooking, and sanitation. Reliance on water distribution by boat is often ineffective due to weather conditions, resulting in an erratic water supply and increasing costs for the community. This situation has triggered complaints and reduced the quality of life for local residents. Therefore, installing a clean water pipeline from the main area to Gusung Island is a strategic solution that not only addresses water availability but also provides a more stable, efficient, and sustainable distribution system. With the underwater pipeline, water supply can be continuous without relying on sea conditions, thereby reducing the risk of water shortages while supporting improved community welfare and future regional development [5].

Furthermore, the construction of the clean water pipeline serves not only as a technical solution to the water crisis but also as a strategic step in supporting improved community well being. The availability of adequate clean water will positively impact health, environmental cleanliness, and community economic activity. Furthermore, this infrastructure can also be a supporting factor in the future development of the Gusung Island region, both in the residential, tourism, and other economic sectors [6].

An equally important issue in the implementation of the submarine pipeline system is the determination of an appropriate pipeline route. Although the primary objective is to deliver clean water efficiently from the mainland to Gusung Island, route selection significantly influences the long-term performance and reliability of the infrastructure. The shortest route is not always the safest or most cost-effective option throughout the lifecycle of the pipeline. Factors such as seabed topography, sediment characteristics, current velocity, wave action, and interactions with maritime activities must be carefully evaluated to minimize future operational risks. A route that is selected without considering these factors may expose the pipeline to excessive external loads and environmental hazards that could affect its structural integrity over time [7].

In addition, route selection has a direct relationship with the long-term integrity of the pipeline system. Pipelines installed in areas with unstable seabed conditions may experience settlement,

free-span formation, or excessive bending stresses that contribute to material fatigue and eventual failure. Similarly, routes located near busy navigation channels face greater risks of accidental damage from anchors, fishing gear, or vessel activities. These threats not only increase maintenance requirements but also raise the possibility of service interruptions that can affect water supply reliability. Therefore, integrating risk-based route assessment into the planning process is essential to ensure both the safety and sustainability of clean water distribution to Gusung Island [8].

Furthermore, the management and maintenance system for the pipeline network must be designed sustainably to ensure the infrastructure continues to function optimally in the long term. The role of both the regional and central governments is crucial in providing policy support, funding, and oversight, while community participation is also needed to maintain and utilize these facilities wisely. With good synergy between technical and managerial aspects, the construction of this clean water pipeline is expected to be not only a short-term solution but also a strong foundation for achieving water security on Gusung Island [9].

Therefore, installing a clean water pipeline from the mainland to Gusung Island is a solution that not only addresses the fundamental problem of water availability but also provides long term, sustainable benefits for the community. This effort is expected to create a more reliable, efficient, and equitable water distribution system, while simultaneously improving the overall quality of life for the community [10].

3. Review and Critique of Existing Approaches

The approach of installing underwater pipelines as a solution to the clean water crisis on Gusung Island is conceptually sound because it overcomes the dependence on unstable ship based water distribution. This system offers a more continuous supply, better control of water quality, and the potential for long-term efficiency. However, this approach also requires critical review, as it is not entirely free from limitations and risks. From a technical perspective, underwater pipeline installation is highly complex, particularly due to aggressive marine environmental conditions such as corrosion, currents, waves, and potential damage from human activity. Without a well thought out design and optimal protection systems, the pipeline is at risk of leaks or damage, which could disrupt long term water distribution. Furthermore, hydraulic aspects such as headloss must be carefully calculated to ensure water reaches the island with adequate pressure [11].

Another limitation frequently observed in submarine pipeline projects is the tendency to prioritize construction feasibility and installation costs over long-term integrity considerations during route selection. In many cases, route planning focuses primarily on minimizing pipeline length and reducing initial capital expenditure. While this approach may provide short-term economic benefits, it can increase exposure to environmental hazards such as unstable seabed conditions, scour zones, and areas with intense maritime activity. As a result, pipelines may experience higher maintenance requirements and greater risks of failure throughout their operational life. Therefore, route selection should be evaluated not only from a construction perspective but also from an asset integrity and lifecycle management standpoint.

Moreover, existing approaches often treat route selection as a one-time planning activity rather than a component of continuous risk management. Marine environments are dynamic and can change over time due to sediment transport, erosion, coastal development, and increasing vessel traffic. Consequently, a route considered safe during the design stage may face new challenges during operation. This highlights the need for periodic reassessment of route-related risks through seabed monitoring, integrity inspections, and updated environmental evaluations. Incorporating these practices into pipeline management can improve the ability of operators to anticipate potential threats and maintain long-term system reliability.

From an economic perspective, the initial investment in building an underwater pipeline is relatively large, encompassing surveys, specialized materials, installation, and supporting technology. Without proper financial planning and needs analysis, these costs can become burdensome, especially if the number of users is limited. Furthermore, long term operational and maintenance costs are often underestimated, even though underwater systems require routine inspections that are not simple. This approach also tends to focus too much on centralized solutions

(supply from land), without considering locally based alternatives such as rainwater harvesting, small scale desalination, or sustainable management of limited groundwater. However, a combination of several systems (a hybrid system) can increase water security and reduce the risk of dependence on a single source [12].

From a social and institutional perspective, the success of this system depends heavily on sound operational management, including equitable distribution, affordable tariffs, and the ability of managing institutions such as the Makassar Water Company (PDAM) or related parties to maintain it. Without effective management, even a technically sound system may fail to provide optimal benefits to the community. Overall, installing underwater pipelines is a promising strategic solution, but it needs to be complemented by thorough technical planning, a realistic economic analysis, and an integrated approach that considers alternative water sources. This way, the implemented solution will not only address short-term problems but also ensure the long-term sustainability and water security of Gusung Island [13].

4. The Author's Perspective or Argument

The installation of underwater pipelines by the Makassar Water Company (PDAM Makassar) is indeed a relevant strategic step to address the instability of clean water distribution. However, the author believes that this solution remains partial if not accompanied by a more comprehensive approach. The author argues that dependence on a single source of supply from the mainland via pipelines creates new vulnerabilities, where even minor disruptions to the system can have significant impacts on the entire community. In the context of small islands, an ideal system should not rely solely on a single primary infrastructure but also include backup or alternative water sources. Therefore, the author believes that a more appropriate approach is the installation of underwater clean water pipelines, combining piping with the use of local water sources such as rainwater harvesting or simple water treatment technologies [14].

The author also argues that route selection should be regarded as a strategic integrity management decision rather than merely a construction planning activity. In submarine pipeline systems, many operational problems originate from conditions that were not adequately considered during the route selection stage. Selecting routes that avoid unstable seabed areas, regions with strong hydrodynamic forces, and busy navigation corridors can significantly reduce the probability of mechanical damage and future maintenance requirements. Therefore, the long-term success of the Gusung Island water supply project depends not only on the existence of the pipeline itself but also on the appropriateness of the route chosen during the early stages of project development.

Furthermore, the author believes that the success of a solution is determined not only by technical aspects but also by management capabilities and operational sustainability. Good infrastructure will not provide maximum benefits without effective management, including maintenance, equitable distribution, and affordability for the community. This includes a monitoring system capable of early detection of disruptions, a consistent routine maintenance schedule, and a rapid response mechanism in the event of damage. Furthermore, transparency in management and tariff setting is also crucial to ensure public access to clean water without excessive costs. Local community involvement in system oversight and utilization is also a key success factor, fostering a sense of ownership and ensuring long term operational sustainability, particularly in areas like Gusung Island [15].

Furthermore, a rapid response mechanism to disruptions is crucial for maintaining system reliability. When a leak or pipe damage occurs, for example, a technical team is needed to carry out repairs quickly to prevent prolonged interruptions in water distribution. Transparency in management, including budget allocation and tariff setting, is also crucial for building public trust in service providers. Without transparency, the potential for social conflict and public dissatisfaction can increase, ultimately jeopardizing the sustainability of the system [16].

Beyond technical and managerial aspects, active involvement of the local community is also a key factor in determining the long term success of this system. Community participation in monitoring, simple maintenance, and wise water use can foster a sense of ownership over the infrastructure that has been built. With a sense of shared responsibility, the community is no longer

merely a passive user but plays a role as part of the system, ensuring the sustainability of clean water services. This is crucial, especially in areas like Gusung Island, where limited access and resources require strong collaboration between the government, management, and the community. With a comprehensive and integrated approach, the clean water supply system will not only be able to meet current needs but will also be able to survive and thrive in the face of future challenges [17].

5. Conclusions

Providing clean water on Gusung Island through an underwater pipeline system is a strategic solution to address the limited freshwater resources and the unstable distribution that has traditionally relied on ships. Technically, this system is capable of providing a more continuous, efficient, and controlled water supply. However, its implementation is not without challenges, such as the risk of corrosion, damage due to sea conditions, pressure loss, and high investment and maintenance costs.

Therefore, the success of this system depends heavily on careful planning, appropriate material selection, and the implementation of risk management and ongoing maintenance. Furthermore, this approach should not be used alone, but rather combined with alternative water sources such as rainwater harvesting or other local technologies to increase system resilience.

Furthermore, providing clean water through underwater pipelines should not be considered the sole solution but should be combined with alternative water sources to increase overall system resilience. Utilizing rainwater through rainwater harvesting, the use of small scale desalination technology, or managing other local water resources can be effective complements. By diversifying water sources, the risk of dependence on a single system can be reduced, allowing the community to maintain a water reserve in the event of disruptions to the main network.

By comprehensively integrating technical, economic, and management aspects, the underwater pipeline system has great potential to be an effective and sustainable long term solution to meet the clean water needs of the Gusung Island community. Not only can it increase water availability, but this system also contributes to improving the quality of life and public health, and opens up opportunities for future regional development. Therefore, well-planned and professionally managed implementation will be key to ensuring the success and sustainability of this system.

In addition, this study highlights that pipeline route selection is one of the most influential factors affecting long-term pipeline integrity. Route-related decisions determine the level of exposure to environmental, geotechnical, and operational risks throughout the lifecycle of the asset. A well-planned route can reduce maintenance requirements, improve system reliability, and minimize the likelihood of service interruptions, whereas an inappropriate route may increase the risk of structural degradation and operational failure. Therefore, integrating route selection into a comprehensive risk management framework is essential for ensuring the long-term sustainability of clean water distribution to Gusung Island.

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