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Route Selection and Environmental Strategies in Subsea Pipeline Engineering

Part of the Book Series "Maritime Engineering"

Undersea Pipeline Installation Perspective: Maritime Challenges in Clean Water Distribution from Kendari City to Bokori Island

Abstract

The availability of clean water is a basic need that is crucial in supporting human life and the development of tourism areas. Bokori Island, as a leading tourist destination, faces limited natural clean water sources, so that the water needs of tourists are not optimally met. This perspective article aims to evaluate the clean water distribution system through an underwater pipeline network from Kendari City to Bokori Island, with a primary focus on mapping maritime challenges in Indonesian waters. The method used is a qualitative analysis of marine environmental conditions, human activities, and operational aspects. The identification results show that although the shallow water route facilitates installation, there are significant risks from human activities such as ship traffic, as well as oceanographic dynamics such as ocean currents and corrosion levels. In conclusion, the underwater pipeline distribution system is a feasible solution, but its success is highly dependent on mitigating external technical risks and selecting appropriate protective materials. This abstract emphasizes the importance of a comprehensive approach without complex mathematical modeling in coastal infrastructure planning.

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1. Introduction

The availability of adequate clean water is a key indicator in supporting the quality of life of communities and the sustainable development of tourism destinations. Tourism activities require a reliable supply of clean water not only for domestic consumption but also for accommodation facilities, restaurants, sanitation systems, and other supporting infrastructure. As tourism activities continue to grow, the demand for water resources also increases significantly, making water availability a critical component of tourism sustainability [1].

Bokori Island, located in the coastal waters of Kendari City, has developed into one of the prominent tourism destinations in Southeast Sulawesi. The island attracts visitors because of its coastal scenery, recreational facilities, and accessibility from the mainland. However, as a small island environment, Bokori possesses limited freshwater resources and lacks sufficient natural water reserves to support increasing tourism activities. Consequently, the availability of clean water remains one of the major challenges affecting the long-term development of the island [2].

The limitations of local water resources on small islands are commonly addressed through several approaches, including rainwater harvesting, groundwater utilization, desalination systems, and water transportation by vessels. Although these methods can provide temporary solutions, each approach has operational and economic limitations. Water transportation by tanker vessels, for example, is highly dependent on weather conditions and often incurs substantial operational costs. Therefore, more reliable and sustainable alternatives are required to ensure continuous water supply [3].

One solution considered technically feasible is the distribution of clean water from Kendari City through an undersea pipeline system. Compared with periodic water transportation, pipeline systems provide continuous flow, better supply reliability, and lower long-term operational costs. Nevertheless, submarine pipeline installations operate within complex maritime environments where infrastructure is continuously exposed to hydrodynamic forces, human activities, and environmental degradation processes [4].

This article aims to evaluate the feasibility of clean water distribution through an undersea pipeline network connecting Kendari City and Bokori Island from a maritime installation perspective. Particular attention is given to the challenges associated with shallow-water environments, including shipping activities, sediment movement, seabed conditions, and corrosion risks. By focusing on these maritime factors, this study seeks to provide a broader understanding of the technical considerations required for the successful implementation of submarine water distribution infrastructure.

2. Materials and Methods

This study adopts a qualitative approach combined with a spatial technical evaluation to assess the feasibility of an undersea clean water pipeline connecting Kendari City and Bokori Island. The analysis focuses on identifying environmental and operational factors that may influence pipeline installation and long-term performance within a coastal marine environment.

The study area covers the coastal waters between Kendari City as the water supply source and Bokori Island as the distribution destination. This corridor was selected because of its relatively short distance and strategic importance for supporting tourism development on the island. Particular attention was given to the characteristics of shallow-water environments, which often present unique installation and maintenance challenges.

Primary information was obtained through field observations, visual inspections of coastal conditions, route reconnaissance, and geographic documentation. Secondary information was collected from scientific literature, engineering standards related to water distribution systems, bathymetric maps, coastal development reports, and previous studies concerning submarine pipeline installations in shallow marine environments.

The route evaluation process considered several technical criteria, including route length, bathymetric conditions, accessibility for maintenance activities, exposure to maritime traffic, and environmental risks. Rather than applying complex numerical simulations, the study employs descriptive analysis to identify major maritime challenges and develop conceptual recommendations for safe and sustainable pipeline installation.

3. Results

The evaluation of the proposed pipeline route indicates that the distribution of clean water from Kendari City to Bokori Island is technically achievable through a submarine pipeline system. The relatively short separation distance between the mainland and the island provides favorable conditions for pipeline installation while reducing transmission losses and operational complexity. However, several maritime challenges were identified that may affect the long-term integrity and reliability of the system.

3.1 Geographical Conditions and Route Requirements

The selected route utilizes the geographical characteristics of the strait separating Kendari City

and Bokori Island. Bathymetric observations indicate that most sections of the proposed corridor consist of relatively shallow waters with gradual seabed slopes. These conditions simplify installation activities and reduce the need for highly specialized offshore construction methods.

The relatively shallow water depth also improves accessibility for future inspection and maintenance operations. Furthermore, selecting a shorter route contributes to reducing construction material requirements and minimizing hydraulic losses during water transmission. Consequently, the route provides several technical advantages compared with longer alternative alignments [5].

The geographical separation between Kendari City and Bokori Island represents a favorable condition for the development of a subsea pipeline system. The relatively short crossing distance reduces installation complexity and allows the pipeline to be placed within a manageable operational corridor. In addition, the shallow-water characteristics of the route may simplify future inspection activities and reduce intervention costs compared with installations located in deeper offshore environments [6].

From an engineering perspective, route selection must also consider shoreline access conditions at both the supply and receiving points. Stable coastal areas with minimal erosion potential are preferred because they provide safer transition zones between land-based and subsea pipeline segments. Consequently, geographical suitability becomes one of the primary factors supporting the feasibility of the proposed clean water distribution system.

3.2 Identification of Subsea Environmental Challenges

Despite the favorable geographical characteristics, several environmental challenges were identified along the proposed route. The shallow-water environment is highly exposed to anthropogenic disturbances, particularly from tourism vessels, fishing boats, and other maritime activities operating near Bokori Island [7].

In addition, natural oceanographic processes such as tidal currents, wave actions, and seabed sediment movement may influence pipeline stability. Continuous sediment transport can gradually expose or bury sections of the pipeline, potentially affecting maintenance accessibility and structural performance throughout the operational life of the system [8].

The environmental conditions identified along the proposed route indicate that pipeline integrity may be influenced by both short-term and long-term seabed changes. Variations in current velocity and wave energy can affect sediment distribution patterns, resulting in localized erosion or deposition around the pipeline corridor. Such changes may alter the level of pipeline exposure and influence maintenance requirements throughout the operational life of the system [9].

Furthermore, seasonal variations in weather and oceanographic conditions should also be considered during project planning. Although the route is located within relatively shallow coastal waters, changes in environmental conditions over time may create additional operational challenges. Therefore, environmental monitoring programs are essential to support long-term infrastructure reliability.

3.3 Human Activity Risks

Human activities represent one of the most significant external threats to the proposed pipeline system. Vessel anchoring activities may directly impact the pipeline if adequate protection measures are not implemented. Similarly, fishing operations involving nets or other equipment may create accidental interactions with exposed pipeline segments [10].

The intensity of maritime activities around Bokori Island is expected to increase alongside tourism growth. Therefore, future operational planning must incorporate maritime traffic management and route protection strategies to minimize the probability of external damage.

The concentration of tourism-related activities around Bokori Island further increases the potential for interactions between maritime users and subsea infrastructure. As visitor numbers continue to increase, marine transportation services and recreational boating activities are expected to become more intensive. Without adequate route marking and protection measures, the probability of accidental damage may also increase over time.

In addition, fishing activities conducted in coastal waters may introduce operational risks,

particularly where fishing equipment comes into contact with exposed pipeline sections. These findings suggest that route planning should incorporate an assessment of existing maritime activity patterns to minimize future conflicts between infrastructure and marine users [11].

3.4 Material and Protection Requirements

The analysis indicates that material selection plays a critical role in ensuring long-term pipeline reliability. The marine environment is characterized by continuous exposure to saline water, which accelerates corrosion processes in metallic infrastructure. Consequently, materials with high corrosion resistance or suitable protective systems are required [12].

Additional protection measures, such as pipeline burial, concrete weighting systems, or mechanical protective covers, may be necessary in areas exposed to high external risks. These measures can significantly improve pipeline stability and reduce the likelihood of damage caused by environmental and operational factors [13].

Material selection should also account for the expected service life of the infrastructure and the environmental conditions encountered along the route. The use of corrosion-resistant materials can significantly reduce maintenance requirements and improve long-term operational reliability. In marine environments, material degradation often occurs gradually and may remain undetected until structural performance is affected.

Beyond material considerations, protection systems should be adapted to local environmental conditions and operational risks. The combination of appropriate material selection, protective measures, and periodic inspections can improve overall pipeline integrity and reduce the likelihood of unexpected failures. As a result, protection strategies become an essential component of sustainable subsea pipeline management [14].

4. Discussion

The findings indicate that the proposed undersea pipeline system between Kendari City and Bokori Island is technically feasible and offers a practical solution to address clean water shortages on the island. The relatively short distance between the mainland and the island reduces transmission complexity and supports continuous water delivery compared with conventional transportation methods such as water tankers. From an infrastructure perspective, a pipeline system provides greater reliability and operational consistency, which are essential for supporting tourism activities that depend heavily on a stable water supply [4].

However, the results also demonstrate that technical feasibility alone is insufficient to guarantee long-term project success. Unlike land-based water distribution systems, submarine pipelines operate within a dynamic maritime environment where external factors continuously influence infrastructure performance. Consequently, the reliability of the system should be evaluated not only based on hydraulic performance but also on its ability to withstand environmental and operational challenges throughout its service life. This perspective highlights the importance of adopting a risk-based approach during both the planning and operational phases.

One of the most significant challenges identified in this study is the potential impact of human activities on pipeline integrity. The waters surrounding Bokori Island are frequently utilized by tourism vessels, fishing boats, and other maritime users. In shallow-water environments, anchor drops, vessel grounding, and fishing activities may create direct physical interactions with subsea infrastructure. Such incidents can lead to localized damage, pipeline displacement, or even service interruptions. Therefore, route planning should consider existing maritime traffic patterns and incorporate adequate protection measures to reduce exposure to these risks [10].

In addition to anthropogenic factors, natural oceanographic processes also represent critical considerations in pipeline design. Ocean currents, wave actions, and sediment transport mechanisms continuously alter seabed conditions and may affect pipeline stability over time. Sediment erosion can expose previously buried pipeline sections, while sediment accumulation may complicate future inspection and maintenance activities. These processes emphasize the need for continuous monitoring and periodic condition assessments to ensure that the pipeline remains secure throughout its operational lifespan [15].

Another important issue relates to material durability in the marine environment. Seawater is inherently corrosive and can significantly accelerate the degradation of infrastructure components if inappropriate materials are selected. For this reason, material selection should prioritize corrosion resistance, durability, and long-term maintenance requirements. The implementation of protective systems, including coatings, cathodic protection, or protective covers, may further enhance infrastructure reliability and reduce lifecycle costs. Ultimately, the success of the Kendari–Bokori clean water pipeline depends on the integration of sound engineering design, environmental risk mitigation, and proactive operational management. Through a comprehensive planning approach, the proposed system can provide a sustainable and reliable clean water supply while supporting the continued development of Bokori Island as a tourism destination.

5. Conclusions

The analysis presented in this study indicates that the installation of an undersea clean water pipeline between Kendari City and Bokori Island is a technically feasible solution for addressing the increasing demand for clean water on the island. As a growing tourism destination with limited natural freshwater resources, Bokori Island requires a reliable water supply system capable of supporting both local communities and tourism-related activities. Compared with conventional water transportation methods, an undersea pipeline system offers the potential for more continuous, efficient, and sustainable water distribution.

The findings also demonstrate that route feasibility is strongly influenced by maritime environmental conditions. Although the relatively shallow waters between Kendari City and Bokori Island provide advantages in terms of installation accessibility and maintenance operations, these same conditions expose the pipeline to various external risks. Human activities such as vessel navigation, anchoring, and fishing operations may threaten pipeline integrity, while natural factors including ocean currents, wave action, and sediment movement can affect long-term stability and performance.

Furthermore, the study highlights the importance of incorporating risk mitigation measures into the planning and operational phases of the project. Material selection should prioritize resistance to corrosion and environmental degradation, while appropriate protection systems should be considered to minimize exposure to physical damage. Detailed route surveys, environmental assessments, and continuous monitoring programs are also essential to ensure safe and reliable operation throughout the service life of the pipeline.

In conclusion, the success of the Kendari–Bokori undersea pipeline project depends not only on hydraulic performance or installation feasibility but also on the ability to effectively manage maritime risks. By integrating sound engineering practices, environmental considerations, and long-term operational planning, the proposed system can provide a sustainable solution for clean water distribution while supporting the continued development of Bokori Island as a strategic tourism destination.

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