Enhancing target detection capability of the vessel traffic service (VTS) system on the Cai Mep - Thi Vai channel

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Abstract:

This study addresses the limitations of the current Vessel Traffic Service (VTS) system in monitoring and ensuring navigational safety on the Cai Mep-Thi Vai channel, a crucial waterway in Vietnam's maritime transport system. This research aims to propose solutions to improve the target detection capability of the VTS system in this area. Through surveys and analysis of the current status, this study identifies the system's shortcomings and proposes solutions such as installing additional radar stations and cameras. The proposed solution offers a systematic approach to enhance the effectiveness of the VTS system in managing and monitoring maritime traffic on the Cai Mep-Thi Vai channel, thereby contributing to navigational safety and security. This study provides feasible solutions that can be implemented in practice to address the limitations of the current VTS system.

Keywords: Vessel Traffic Service (VTS); Target detection; Cai Mep - Thi Vai channel; Radar station.

1. Introduction

Vessel Traffic Services (VTS) play a crucial role in enhancing maritime safety, security, and environmental protection within a defined area. The establishment of an effective VTS system requires careful consideration of various factors, including strategic location and coverage area. With increasing maritime traffic and the development of new port facilities in the Cai Mep-Thi Vai area, the existing VTS system faces challenges in providing comprehensive monitoring and traffic management services.

This study aims to address the need for additional VTS stations to ensure seamless coverage and effective traffic management along the Cai Mep-Thi Vai waterway. The proposed solution involves the selection of suitable locations for new VTS stations, considering factors such as geographic constraints, existing infrastructure, and future port developments.

The selection process involves a comprehensive analysis of waterway characteristics, including waterway geometry, traffic patterns, and potential obstructions. Additionally, this study considers the integration of new VTS stations with the existing system, ensuring seamless communication, data sharing, and coordinated operations.

The establishment of additional VTS stations along the Cai Mep-Thi Vai waterway is expected to enhance maritime safety, facilitate efficient traffic management, and support growing maritime activities in the region. This study presents a detailed methodology for site selection that addresses technical

considerations, regulatory requirements, and stakeholder perspectives.

By providing robust and comprehensive VTS coverage, the proposed solution aims to contribute to the sustainable growth of the maritime industry in the region while prioritizing safety, security, and environmental protection.

2. Related works

Ensuring maritime safety and efficient waterway traffic management have become crucial as the number of vessels operating on waterways continues to increase. Vessel Traffic Service (VTS) systems play a vital role in monitoring and regulating vessel traffic to enhance safety and operational efficiency [1]. However, with increasing vessel traffic, existing VTS systems may be inadequate to meet monitoring demands, necessitating research into optimizing the location of VTS radar stations.

Previous studies have focused on improving the monitoring and traffic management capabilities of VTS systems by incorporating additional systems or equipment [2], [3]. However, these studies did not address the optimization of VTS radar station locations. Other research has analyzed the tasks and performance of VTS operators [4], [5], [6], and their working environments [7]. Although these studies contribute to enhancing the operational efficiency of VTS systems, they do not address the issue of optimizing radar station locations.

Additionally, some studies have concentrated on developing electromagnetic wave propagation models to accurately predict the propagation process of radar signals [8]-[17]. These models play a crucial role in assessing the feasibility and effectiveness of radar systems at specific locations.

Regarding solution methods, papers have discussed the use of meta-heuristic algorithms such as Genetic Algorithms (GA) [18], Particle Swarm Optimization (PSO) [19], and Ant Colony Optimization Algorithm (ACO) to solve facility location optimization problems [20]. Furthermore, exact methods such as Lagrangian relaxation, branch and bound, and the Benders decomposition method have been mentioned [21].

This study primarily focuses on employing an expert-based approach in selecting locations for new radar stations. The author emphasizes the significance of conducting comprehensive site surveys and adhering to specific principles and criteria during the location optimization process.

The site selection process involved a thorough analysis of geographical constraints, existing infrastructure, and future port development along the Cai Mep-Thi Vai waterway. The author proposed a set of guiding principles, including maximizing the utilization of available land and water resources, ensuring comprehensive coverage and visibility of the entire waterway, prioritizing safety for personnel and equipment, and aligning existing and planned port facilities in the area.

The expert-based approach entails a rigorous evaluation of potential site locations through on-site inspections, analysis of topographical data, and consideration of various factors, such as elevation, obstructions, and proximity to existing infrastructure. The author highlights the importance of involving domain experts, including maritime authorities, port operators, and technical specialists, to leverage their collective knowledge and expertise in the decision-making process.

By employing this expert-based approach, the author aims to identify optimal locations that not only meet the technical requirements for radar station operations but also address practical considerations related to construction feasibility, operational efficiency, and long-term sustainability within the complex maritime environment of the Cai Mep-Thi Vai waterway.

3. Actual situation of operation

Current monitoring capabilities of the VTS system in the Saigon - Vung Tau channel: The system is capable of monitoring maritime activities along the entire Saigon - Vung Tau channel and a portion of the Soai Rap channel, with the following details:

Table 1. Target detection range of Nui Lon radar.

Nui Lon Radar (285 meters above sea level)	**Target detection range (NM)**	
Target height	**Good weather, sea state 2**	**Rain (10mm), sea state 2**
1	7.3	7.0
2	27.4	13.4
3	31.2	17.7
5	36.1	31.7
8	39.4	36.2

Source. Maritime administration of Ho Chi Minh City.

Camera system - CCTV (Camera Surveillance System): Capable of monitoring maritime activities in the Ho Chi Minh City port area, from the Nha Be anchorage, Lotus port, Tan Thuan Dong port, Saigon-Khanh Hoi port, to the Ba Son port area.

Radar system: Consists of three radars capable of monitoring targets along the Saigon - Vung Tau channel and the Vung Tau sea area within a circular range of 12 nautical miles radius from the Nui Lon Radar station.

Shore-based AIS station: Located at the top of Nui Lon mountain - Vung Tau, at an altitude of 286m above sea level, capable of identifying targets equipped with AIS within a radius of 63 km (34 nautical miles). Under normal weather conditions, the shore-based AIS station of the VTS system in the Saigon-Vung Tau channel can provide coverage for the entire Saigon-Vung Tau channel and the Vung Tau area.

This paper presents and assesses the current situation of maritime traffic management in the Cai Mep-Thi Vai channel area for the Vung Tau VTS Center and the Vung Tau Maritime Administration as challenging and unable to ensure safe navigation for vessels under conditions of limited visibility. This is due to the lack of signal transmission from the Cai Mep-Thi Vai channel to the headquarters for traffic management, monitoring, and coordination, especially in cases of heavy rain, storms, and adverse weather conditions during natural disaster prevention and search and rescue operations within the area of responsibility. The author also clarifies the limitations in management equipment and facilities amidst the increasing density of maritime traffic, vessel flow, vessel size, and the growing number of means of waterway transport.

4. Identify criterias that influence the choice of options

As part of a comprehensive survey, 20 experts in the maritime industry were consulted to identify and assess the critical criteria for evaluating the feasibility and effectiveness of a Vessel Traffic Service (VTS) system in the Cai Mep-Thi Vai channel. These experts, with extensive experience in port management, navigational safety, and maritime operations, provided valuable insights that led to the establishment of the following criteria:

(i) Ability to monitor activities along the entire channel.

- Coverage of Camera system.
- Coverage of Radar system.

(ii) Potential interference from construction works and forest trees.

• Crane systems at existing ports along the Thi Vai River.

• Power lines crossing the river at Go Dau.

• Phuoc An Bridge.

• Forest trees.

(iii) Land availability for construction.

(iv) Technical infrastructure (electricity supply, water supply, transportation).

(v) Construction investment costs.

(vi) Construction work management.

(vii) Operation, exploitation, and maintenance management.

(viii) System safety and reliability.

The 10 experts, including 2 specialists from Terma Denmark and 8 Vietnamese experts from the Maritime Administration (3 people), Pilotage (2 people), and the Construction Consultation Joint Stock Company for Maritime Building (3 people), unanimously agreed that these criteria are essential for evaluating the VTS system's capability to ensure safe and efficient navigation in the Cai Mep-Thi Vai channel. They stressed the importance of considering unique geographical features, existing infrastructure, and potential challenges in the area when designing and implementing a VTS system.

The experts also emphasized that these criteria will assist decision makers in assessing the project's feasibility, allocating resources effectively, and ensuring the smooth operation and maintenance of the VTS system. By considering these factors, the maritime industry can enhance safety, reduce the risk of accidents, and support the sustainable growth of shipping activities in the region.

The consensus reached by the 10 experts, comprising both international and local professionals with extensive experience in maritime technology, navigation, and construction, highlights the significance of these criteria in the planning and implementation of a robust VTS system in the Cai Mep-Thi Vai channel. Their diverse backgrounds and expertise provide a comprehensive perspective on the key considerations for the successful development and operation of a VTS system in this critical maritime hub.

5. Evaluation results

5.1. The results of survey

The results are presented in Table 2.

Table 2. Evaluation results from experts.

No.	Comparison criteria	Option 1	Option 2
1	Ability to monitor activities along the entire channel	Around 29%	Around 29%
	Camera coverag	Around 60%	Around 90%
	Radar coverage		
2	Susceptibility to interference from construction works and forest trees		
2.1	Crane systems at existing ports along the Thi Vai River	Less affected	More affected than Option 1
2.2	Power lines crossing the river at Go Dau	Less affected, similar to Option 1	
2.3	Phuoc An Bridge	Less affected, similar to Option 1	

No.	Comparison criteria	Option 1	Option 2
2.4	Forest trees	Affected	Not affected
3	Land availability for construction	Limited at Radar Station No. 2 - Can Gio side, located within the Can Gio Mangrove Biosphere Reserve	Available land for construction
4	Technical infrastructure (electricity, water supply, transportation)	Limited (almost nonexistent) at Radar Station No. 2 - Can Gio side, lacking infrastructure	Ensured
5	Construction investment costs	As per approved estimate	As per approved estimate
6	Construction work	Limited to Radar Station No. 2 - Can Gio side	Convenient
7	Operation, exploitation, and maintenance	Limited and high costs at Radar Station No. 2 - Can Gio side	Convenient, lower than Option 1
8	System safety	High risk for the underground power system crossing the Thi Vai River	No risk, unlike Option 1

Based on the analysis of the advantages and disadvantages mentioned above, Option 1, which involves constructing two radar stations in Can Gio and Phuoc An, has significant advantages in terms of construction costs and minimal impact from existing structures during operation and exploitation. However, the biggest drawback of this option is the location of the downstream station on the Can Gio side:

The ability to arrange land for construction is difficult because of its location within the Can Gio forest, which is part of the national biosphere reserve. Therefore, project preparation progress is likely to take longer than expected.

Operations and maintenance face many difficulties because stations are isolated and can only be accessed by small waterway vehicles.

The construction cost of the station is high owing to the need to install a medium-voltage underground cable crossing the Thi Vai River to supply power to the station. This underground cable line poses a high risk of damage caused by marine accidents in the channels.

The main disadvantage of Option 2 is that it requires a larger number of stations compared to Option 1 owing to the influence of port construction works and the fact that the stations must be located on one side of the Thi Vai River to avoid the Can Gio forest area (which carries the disadvantages of Option 1). As a result, the investment cost increases compared to the initial estimate (owing to the increased number of stations, although the electrical system investment is simpler and cheaper). Apart from these main drawbacks, Option 2 has more prominent advantages than Option 1 in terms of construction, operation, and maintenance of the system equipment. Therefore, selecting Option 2 as the basis for detailed planning and construction of additional items, including three radar stations along the Cai Mep-Thi Vai channel and upgrading the Vung Tau VTS Center, ensures strict, timely, and efficient monitoring zone division**.**

5.2. Survey results for selecting construction locations

Figure 1. Overview of the Cai Mep-Thi Vai channel.

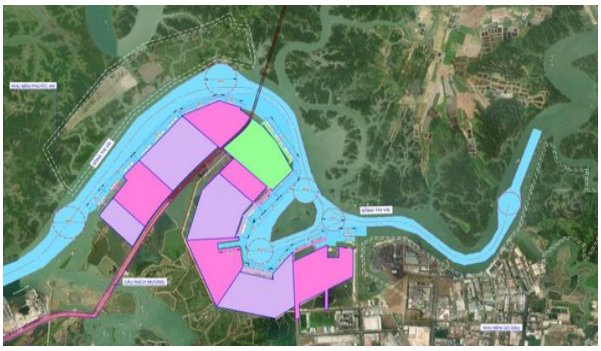

Figure 2. Survey results at the Phuoc An area - obstructed by the planned bridge across the river, with a clearance height of 55 meters, which will block the radar's detection range.

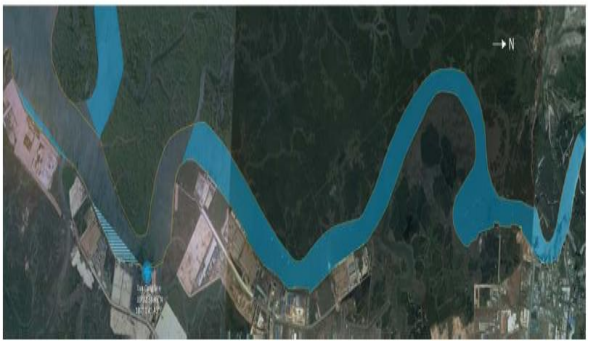

Figure 3. Calculation results of the target detection capability of the radar near Tan Cang port (the area not shaded in blue).

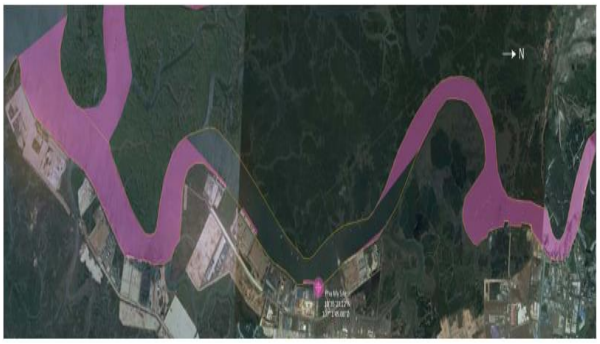

Figure 4. Calculation results of the target detection capability of the PTSC radar (the area not shaded in pink)

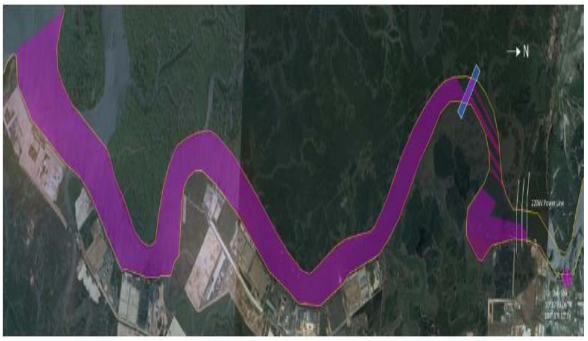

Figure 5. Calculation results of the target detection capability of the Go Dau A radar (the area not shaded in purple).

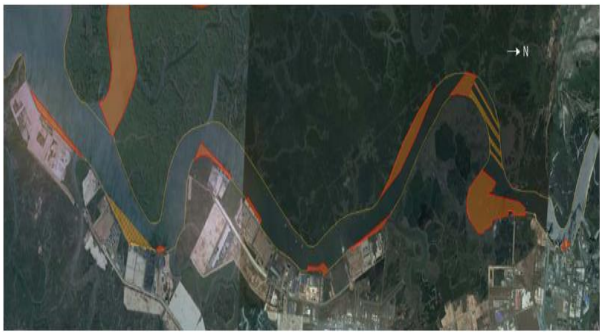

Figure 6. Detection capability for small targets along the channel (the area not shaded).

5.3. Calculation results of new station location

Table 3. Calculation results of the target detection ability of the station location.

No.	Target type	Cross-sectional area (m^2)	Height above water (m)
1	Small watercraft (fishing boats, small speedboats, etc.)	1	1
2	Fishing boats, speedboats, and similar vessels	3	2

No.	Target type	Cross-sectional area (m^2)	Height above water (m)
3	Aids to navigation with radar reflectors	10	3
4	Small metal ships, fishing boats, supply vessels	100	5
5	Offshore platforms	1,000	8
6	General cargo ships, bulk carriers	10,000	12
7	Container ships, tankers	100,000	18

Through research and synthesis of the results from the analysis of the locations in the site selection survey report, considering the natural terrain characteristics of the channel, the proposed radar system at the surveyed points encounters certain “blind area.” Therefore, in addition to the radar placement, it is necessary to supplement camera station locations to overcome the radar's “blind spots.” Moreover, based on the actual operations of watercrafts in the area, small vessels that have not been equipped with radar transceivers and AIS cannot be monitored and managed without the support of the camera system.

5.4. Location and number of required radar stations

The system is designed to have a coverage range that encompasses the entire Cai Mep - Thi Vai channel. As a result, construction works spanning the operational area are located within the provinces of Dong Nai and Ba Ria-Vung Tau, specifically as follows:

Radar Station No. 1 (Go Dau A Radar Station) is situated within the Go Dau A port area, in the district of Long Thanh, Dong Nai Province.

Radar Station No. 2 (PTSC Radar Station) is located within the Phu My Fertilizer and Petrochemical Complex port area in the Phuoc Hoa commune, Tan Thanh district, Ba RiaVung Tau Province.

Radar Station No. 3 (Tan Cang Radar Station) is positioned on the left side of the Tac Xep Canal, on the land bordering the InterFlour port and Tan Cang Cai Mep port in the Phuoc Hoa commune, Tan Thanh district, Ba Ria-Vung Tau Province.

Radar Station No. 4 (Utilizing the existing Nui Lon Radar Station) is situated atop Nui Lon Mountain in Ward 2, Vung Tau City, Ba Ria-Vung Tau Province.

6. Conclusion

This study has achieved significant results in addressing the limitations of the current Vessel Traffic Service (VTS) system in the Cai Mep-Thi Vai channel. First, the research has established a comprehensive set of criteria for evaluating the installation of new radar stations, taking into account factors such as the ability to monitor activities along the entire channel, potential interference from construction works and forest trees, land availability, technical infrastructure, construction costs, and system safety. Second, the study conducted a thorough analysis of the radar coverage calculations, identifying the optimal locations for the new radar stations to ensure maximum coverage and minimize blind spots. The results indicate that the proposed radar system, supplemented with camera stations, can effectively monitor vessel traffic along the entire Cai Mep - Thi Vai channel. Finally, the required numbers and locations were determined. These findings provide a solid foundation for the implementation of an improved vessel traffic management system, which ultimately contributes to the safety and efficiency of maritime transportation in the region.

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