Thoughts on Intelligent Dispatching and Navigation during the Construction Period of the New Waterway of the Three Gorges Project

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Abstract: During the construction period of the new waterway of the Three Gorges Project, the navigation environment is characterized by the dynamic change of the construction scene, the obvious fluctuation of the ship flow and the sharp increase of the safety control pressure. As the "last kilometer" of navigation dispatch, the departure link directly determines whether the ship can enter the lock safely and orderly, and is the key node of navigation guarantee during the construction period. This paper takes the intelligent launching system as the research object, based on the actual construction of the new channel, systematically analyzes the specific challenges faced by the launching link during the construction period from the four dimensions of the launching rule adaptation, the secondary scheduling mechanism, the security alarm system and the man-machine cooperation mode, and puts forward the targeted optimization path.

Keywords: New Channel; Navigation Guarantee; Intelligent Launching; Secondary Dispatching; Man-Machine Cooperation

1. Introduction

As the key node of the Yangtze River Golden Waterway, the Three Gorges-Gezhouba Project undertakes the important mission of ensuring regional economic and social development and the transportation of people's livelihood materials [1]. With the advancement of the new waterway of the Three Gorges Project [2], the navigation environment is constantly changing, and the navigation dispatching work is facing unprecedented complex challenges [3], and the existing intelligent dispatching function modules need to be optimized to adapt to the new challenges [4-6].

Starting from the actual operation logic of the departure system [7], this paper systematically analyzes the challenges faced by the departure link during the construction period [8-9], and puts forward the targeted optimization path [10]. The research is based on the functional architecture and operation rules of the navigation scheduling module, which aims to provide operational reference for the fine optimization of the navigation scheduling system during the construction period.

2. Core Challenges Faced by the Shipping Link during the Construction Period

After the start of the construction of the new water transport channel of the Three Gorges Project, the scope of the construction water area, the shape of the navigation section and the organization mode of the ship flow have changed significantly. These changes not only increase the difficulty of scheduling, but also change the operation scenario of the departure link from the underlying logic. Abnormal situations that only occur occasionally in normal operation have increased significantly during the construction period, and even become normal. Some constraints that do not exist originally arise from construction activities and become restrictive factors that must be rigidly observed. To this end, we combed the change factors introduced by the new channel construction one by one against the existing functions of the departure system, and evaluated their impact on each sub-module, so as to identify the following four systemic challenges.

2.1 Inadequate Suitability of the Rules of Sailing

He rule engine of the existing navigation system is mainly designed for normal navigation conditions, and its parameter system and logical branches are based on stable channel boundary, fixed mooring resources and predictable lock operation rhythm. However, the construction of new corridors has brought about three structural changes:

Firstly, the difference of traffic restrictions on different types of ships in the construction area is aggravated. For example, dangerous goods ships need to avoid the blasting impact area, passenger ships have additional sensitivity to construction noise and visual obstruction, while the route selection of ordinary cargo ships is relatively flexible. These differences require the launching system to dynamically assign different priorities, recommended routes and safe distances according to the ship category, but the current rule engine has not yet achieved the shunting configuration of classification parameters, and still handles all ships with a unified strategy.

Secondly, periodic or irregular control periods (such as blasting operation, hoisting of large components, etc.) are set in the construction waters. Ships crossing the waters must strictly fall within the permitted time window. If they arrive too early, they need to wait at anchor outside the area. If they arrive too late, they may miss the window of the day. This kind of "time window constraint" has no corresponding expression form in the existing rule system, and can only rely on the manual judgment and oral instructions of dispatchers, which not only increases the workload, but also easily causes the illegal passage of ships due to the lag of information transmission.

Thirdly, the construction of the new channel occupies part of the original anchorage resources, which is limited by the reduction of the number of anchorages, and the frequency of changes in the anchorage plan will increase compared with the daily. However, there is a delay in data synchronization between the mooring plan management module and the sailing decision module-after the anchorage adjustment, the sailing system may still use the old plan to generate sailing instructions, resulting in the contradiction between the mooring position received by the ship and the sailing time, and the confusion of on-site execution.

2.2 The Adaptability of the secondary Dispatching Mechanism Is Insufficient

The secondary scheduling module acts as a "diverter valve" on the two nodes of Liantuo (up) and Shipai (down), and its core task is to determine whether the ship is directly heading for the dolphin to wait for the lock or entering the anchorage to wait first. The accuracy of this judgment directly affects the utilization rate of the lock and the turnover efficiency of the anchorage. The construction of new channels makes the basic conditions on which this judgment depends drift:

On the one hand, the judgment parameters used in the secondary dispatch (such as "when the upstream ship arrives at Liantuo, if it is less than 2 hours from the planned departure time, it will go straight, otherwise it will anchor") were originally fixed empirical values, and their values were based on the normal operation interval of the lock and the speed of the channel. During the construction period, the operation interval of the ship lock may be temporarily lengthened due to the coordination of construction, and the navigation window period may also be compressed. The 2-hour threshold is too loose in some scenarios (causing the ship to arrive at the dolphin early without entering the lock for a long time), and too tight in other scenarios (causing the ship that can go straight to enter the anchorage by mistake and increasing the pressure on the anchorage). Since the system does not provide a dynamic adjustment mechanism for the threshold, the parameter cannot be modified with the change of the construction phase.

On the other hand, the key calculation basis of secondary scheduling is "the difference between the current time and the time when the pier can be reached", in which the "time when the pier can be reached" depends on the prediction of the free time of the berthing pier. During the construction period, the actual time consumption of each operation node (lock entry, lock closure, water filling and discharge, and lock exit) fluctuates, the credibility of the planned timetable decreases, and the prediction error of the free time of the berthing dolphin enlarges, resulting in frequent inaccuracy of the diversion decision.

In addition, during the construction period, the plan is frequently adjusted, and the ship is often in the intermediate state of "having the number of locks but no anchoring plan", "having the anchoring plan but no number of locks" or "neither". The existing system does not set clear automatic processing rules for such ships, and dispatchers can only check one by one and intervene manually, which is inefficient and easy to miss.

2.3 Coverage Gap of Safety Alarm System during Construction Period

The existing safety alarm module has been able to effectively identify the conventional risks such as speeding, stalling, intruding into the prohibited navigation area, running the red light, weighing anchor overtime, launching overtime and so on. However, the construction of the new channel introduces new risk forms, which are not covered by the existing alarm logic:

There are temporary operation areas, mud dumping areas and restricted navigation routes in the construction water area, and the boundaries of these areas change daily with the construction progress. Although the system has the function of supervising the prohibited navigation area, the solidified electronic fence can not follow the change of the construction area in time, resulting in the ship entering the construction area by mistake or deviating from the temporary route, the system can not automatically identify and warn, and the risk can only be found by the on-site patrol ship.

When the system manually generates the navigation window period, if the ship does not pass through the construction area in the window (early intrusion or delayed detention), there is no automatic prompt in the system at present. Dispatchers need to continuously pay attention to the real-time location of multiple ships and compare it with the window period, which is a heavy workload and easy to neglect. Once the ship is forced to pass during the prohibited navigation period, it will directly threaten the safety of construction personnel and lock facilities.

During the construction period, a large number of heavy machinery and temporary facilities may block or interfere with Beidou/GPS signals, and the loss and drift of ship positioning data will increase. The system triggers the alarm according to the original sensitivity, resulting in a sharp increase in the number of false alarms, and the dispatchers are tired of verifying, which reduces the vigilance of the real danger.

2.4 Man-Machine Coordination Mechanism is facing a Greater Test during the Construction Period

The departure system supports automatic and manual modes, which can be switched by the dispatcher as required. The construction of new channels has significantly increased the frequency of uncertain events (such as temporary closure, emergency avoidance, equipment failure), and the number and complexity of human-computer interaction far exceed the design expectations, exposing the shortcomings of the existing coordination mechanism:

The decision of mode switching lacks data support. The system can only passively wait for dispatchers to judge whether to switch to manual mode according to their experience, and does not actively provide real-time monitoring and prompting of trigger conditions such as construction control and meteorological changes. When to switch from manual to automatic, and whether the original departure plan needs to be adjusted in batches after switching, the system does not give auxiliary suggestions, and all rely on manual verification one by one.

The operation process of manual intervention is redundant and error-prone. If the dispatcher finds that the automatic departure time of a gate is unreasonable, it is necessary to follow the steps of "switching to manual operation → adjusting time → storing parameters → switching to automatic operation", and the manual emphasizes that "this step must not be forgotten". During the construction period, this kind of adjustment may occur dozens of times every day, with many operation steps and high risk of forgetting. Once the recovery steps are missed, the subsequent brake times will all stay in the manual mode and lose the ability of automatic optimization.

The decision-making basis, operation results and subsequent effects of each manual intervention are not recorded systematically, and there is a lack of re-analysis. This makes the scheduling experience unable to precipitate into systematic knowledge, and similar problems occur repeatedly but always rely on manual repeated processing, which makes it difficult to form a progressive cycle of "intervention-feedback-optimization".

3. Optimization Path of Intelligent Navigation System during Construction Period

Combined with the challenges faced in the construction period, the optimization path is refined from four aspects for the automatic launching module. As shown in Figure 1:

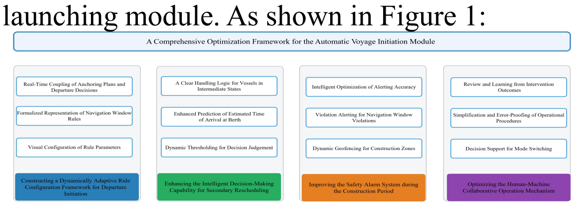

Figure 1. Optimization Path Diagram

3.1 Construct a Dynamic Adaptive Sailing Rule Configuration System

Operational data from a typical operating day of an inland navigation hub were selected as the reseVisual configuration of the rule parameters. The sailing rules are decoupled from the code level, and a rule configuration interface is constructed, so that dispatchers can complete the following operations without relying on technicians: switching rule templates according to construction stages (such as first-stage cofferdam, second-stage foundation pit, third-stage metal structure installation, etc.); setting differentiated sailing strategies according to ship types (dangerous goods grades, passenger ships, general cargo ships); The departure interval parameters are dynamically adjusted according to the operation mode of the lock (level 4/level 5).

Regularized expression of navigation window period. Add "Time Window Constraint" as a basic rule type in the rule engine. The system automatically generates a time window for the crossing ship to pass through according to the control period of the construction area, and matches and verifies the expected arrival time of the ship in the construction area with the window period when making the sailing decision. If the matching fails, the system will automatically postpone the sailing or anchor in advance to ensure that the ship passes within the window period.

Real-time linkage between mooring plan and sailing decision. Get through the data link between the mooring plan input system and the sailing rule engine, and realize the real-time subscription and response of the mooring plan change. When the mooring plan of a ship changes, the system automatically re-evaluates the sailing time and instruction content of the ship to avoid instruction conflicts caused by inconsistent data.

3.2 Upgrade the Intelligent Judgment Ability of Secondary Dispatching

Dynamization of judgment threshold. The core judgment threshold of Liantuo and Shipai secondary scheduling is upgraded from a fixed parameter to a configurable policy parameter. The dispatcher can dynamically adjust the threshold according to the construction stage, navigation flow, anchorage occupancy rate and other factors, and the system automatically records the context of each adjustment and evaluates the adjustment effect.

The prediction of the arrival time of the pier is enhanced. In order to solve the problem of inaccurate prediction of the free time of berthing dolphin during the construction period, a dynamic prediction mechanism based on the real-time execution progress of sluice times is introduced. The system tracks the time of key nodes such as ship entering, closing, filling and discharging, and leaving the lock in the current lock in real time, and on this basis, updates the free time of the berthing dolphin of the subsequent lock in a rolling way, rather than simply relying on the planned time for calculation.

Explicit processing logic for intermediate state ships. Establish the processing rules for three intermediate States: "with sluice plan but without anchoring plan", "with anchoring plan but without sluice plan", and "without both". In the first two cases, the system will automatically handle according to the established rules (for example, the non-dangerous goods ship without anchoring plan will automatically start sailing when it arrives at the collision line point); in the third case, the system will automatically trigger the alarm and recommend the handling suggestions, and will no longer rely on manual discovery afterwards.

3.3 Improve the Safety Alarm System during Construction

Dynamic electronic fence in the construction area. Based on the information of construction stage, the electronic fence which can be dynamically updated is constructed to automatically cover the construction area, the prohibited navigation area and the restricted navigation area. The system monitors the spatial relationship between the ship's location and the electronic fence in real time, and triggers the graded early warning immediately for ships entering the prohibited navigation area and deviating from the restricted navigation area.

Violation alarm during the navigation window period. After the system allocates the navigation window period for the ship, it automatically monitors the time when the ship passes through the key nodes in the construction area. If the ship fails to pass within the window period, the system will automatically trigger the alarm and record the violations, which will provide the basis for the subsequent safety traceability and responsibility identification.

Intelligent optimization of alarm accuracy. Aiming at the problem of increasing false alarms caused by signal interference during construction period, a signal quality evaluation mechanism is introduced. The system scores the confidence level of each ship's positioning signal, presents the signal quality information when triggering the alarm, and assists the dispatcher to judge the authenticity of the alarm. At the same time, the closed-loop process of "confirmation-disposal-filing" of alarm is established to ensure that each alarm has a clear disposal record.

3.4 Optimize the Operation Mechanism of Man-Machine Cooperation

Assisted decision making for mode switching. When the system detects that the meteorological conditions (strong wind and heavy fog) reach the preset threshold, or the construction control information indicates that it is about to enter the no-navigation period, it will actively remind the dispatcher to evaluate whether to switch to the manual mode, rather than only stating the operation requirements in the User Manual. When the automatic mode is restored, the system will automatically check whether the departure time of each gate needs to be adjusted, so as to avoid unreasonable departure plan after switching.

Simplification and error prevention of operation process. In view of the operation link of "switching manual operation first → adjusting parameters → switching automatic operation later", it is designed as an atomic operation-the dispatcher only needs to submit the application of "plan adjustment", and the system automatically completes the whole process of mode switching, parameter modification and mode recovery, and gives a clear prompt after the operation is completed. At the same time, the mandatory recording mechanism of the operation log shall be established, and the operation reasons shall be filled in for all key operations.

Review and learning of intervention effect. The recording and analysis module of manual intervention is established, and the system automatically collects the trigger conditions, operation types, adjustment ranges and actual effects of each intervention (such as whether congestion is avoided and whether potential safety hazards are eliminated). Based on historical intervention data, high-frequency intervention scenarios are identified to promote the optimization iteration of automatic decision rules in corresponding scenarios, so as to realize the continuous evolution of "more intelligent with more use".

4. Conclusion

The optimization of the intelligent navigation system during the construction period of the new Three Gorges waterway is essentially the continuous refinement of the navigation decision-making logic and the systematic coverage of abnormal scenarios. Sailing, as the connection node between sluice plan and ship behavior, is the key link of navigation guarantee during the construction period.

Looking forward to the future, with the progress of construction and the accumulation of operation data, the intelligent navigation system will gradually form a complete closed-loop of "perception-decision-execution-review", which will provide more solid support for the construction of the new waterway of the Three Gorges and the smooth and safe operation of the golden waterway.

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