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Optimizing ship guidance service time based on movement order fluctuations: An applied nonlinear analytics and Markov chain analysis approach

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Abstract: Ship piloting services at ports are crucial for ensuring safety and efficiency. This process requires pilots to control ships by considering various dynamic factors such as wind, currents, and environmental conditions. This research aims to optimize guiding service time based on fluctuations in movement commands issued by guides. Using Markov Chain analysis, this study examines MV ship movement command data during simulation training at the Semarang Seafaring Science Polytechnic. The results demonstrate that the Markov Chain method effectively identifies movement command patterns and the duration needed to achieve "finish with engine" (FWE). Consequently, this research establishes a standard for pilot service times that can serve as a reference for evaluating pilot competency and optimizing port resources. In conclusion, this analysis can support improvements in the quality of safe and efficient pilotage services at ports.

Keywords: *Markov chain, Optimization of guidance, Service time, Ship guidance, Ship maneuvering.*

1. Introduction

Ship piloting is an essential service in port activities around the world, aiming to ensure safety, efficiency and punctuality for ships operating in heavily trafficked waters. Globally, the increasing volume of international trade causes port traffic to become increasingly congested, so improving pilotage services becomes an urgent need.

In Indonesia, regulations such as Government Regulation no. 81 of 2000 regulates the importance of appropriate and safe pilotage services, especially at major ports which are gateways to international trade. Inefficient pilotage processes can result in increased waiting times, higher operational costs and increased safety risks, all of which have an impact on productivity and port reputation.

Many factors influence the effectiveness of pilotage services, ranging from ship characteristics such as size and type of engine, to external factors such as weather conditions, ocean currents and wind.

The speed of the ship's movement also depends greatly on the pilot's skills in navigating the ship in a complex environment.

For example, differences in “engine telegraph movement” (ETM) during the piloting process may result from the pilot's intuition adjusting commands according to changes in surrounding conditions. Factors create variability in service times, and require drivers to have expertise in dealing with dynamically changing situations.

The impact of these various factors can be seen in the length of service time and the overall efficiency level of the port.

Service times that are too long result in longer ship berthing times, so that ports cannot maximize their capacity to handle more ships.

Another effect is additional costs for ship owners due to high waiting times at ports, thereby potentially reducing port competitiveness.

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This research involves fluctuations in movement commands in the ship piloting process, with more detailed analysis using the Judge and Swanson [1] Markov Chain model.

The data used includes MV movement records. Sinabung during training in the Full Mission Ship Simulator (FMSS) at the Semarang Seafaring Science Polytechnic.

The Markov Chain method makes it possible to model transition patterns in various ship engine command conditions, as well as estimate the time required to reach the final condition.

These maneuver command fluctuations are very complex because they are influenced by the pilot's intuition as well as external factors, such as sea currents and wind, which change the ship's control patterns significantly.

This research has a unique use, namely the application of Markov Chain analysis to understand movement patterns in a very dynamic context.

The novelty of this research lies in the analytical ability to describe movement patterns and service times based on dynamic data generated from the FMSS simulator, so that it can become a standard reference for service times for pilots in large ports.

Previously, similar research tended to focus on static aspects of guiding services without considering the complexity of fluctuating movements.

The urgency of this research arises in line with more measurable demands and service time standards in large ports.

It is hoped that this research will be able to make a significant contribution to the development of time service standards that are more precise and can be widely applied in Indonesian ports, especially in reducing operational costs and increasing the efficiency of pilotage services.

The main objective of this Diklat Perhubungan [2] research is to identify the number of movements and duration of time required to complete the MV piloting process. Sinabung.

This research also aims to develop service time standards based on movement command transition patterns so that they can be used as a reference in evaluating the performance of guides and as a tool for training prospective guides in the simulator.

The benefits of this research are divided into several aspects: for educational institutions, standard pene results in competency assessment during exercise training in simulators.

For ports, the findings of this research can be a reference in evaluating the competency of guides and the effectiveness of available facilities.

Furthermore, this research can provide recommendations regarding the length of training time needed to ensure pilot competency before duty, thereby increasing safety and service efficiency at the port.

2. Method

This research uses a descriptive qualitative approach, aiming to understand and describe in detail the patterns and dynamics of movement orders in ship piloting services at ports.

With this approach, the research seeks to explore the factors that influence the effectiveness of pilotage services and identify service time patterns based on simulation data in the Full Mission Ship Simulator (FMSS) laboratory of the Alawadhi and Konsowa [3] Semarang Shipping Science Polytechnic.

The selection of the FMSS location was based on the laboratory's ability to provide a simulated environment that is close to real conditions, so that the resulting data reflects the situations faced by scouts in actual practice.

This research was carried out over a planned period of time including several simulation sessions. This time period allowed the study to collect repeated data from a number of sessions to gain a comprehensive understanding of motor commands.

With this simulation, aspects such as speed change patterns, ship direction, and the influence of external conditions such as wind and currents can be observed and analyzed.

This understanding is very important to identify the guide's skills in managing movement orders in order to achieve optimal service time.

The main aspects analyzed in this research include (1) the pattern of movement commands on the telegraph movement engine (ETM), (2) the influence of external factors that add to the challenges in controlling the ship, and (3) the dynamics of pilot decision making in certain situations.

These three aspects were chosen because of their relevance in ensuring safe and efficient pilotage services, especially in large ports that require accuracy and speed in handling high ship traffic.

The main research instrument is a log of movement commands generated by ETM during simulations in FMSS.

This data log records Artana [4] every command given by the pilot and includes details of the time and changes made to the ship's speed and direction.

This data is then analyzed to identify emerging patterns, thereby providing a clear picture of the duration and type of command that is most effective in completing scouting.

Data collection was carried out carefully over several sessions to ensure that the results obtained were accurate and could describe patterns in a representative manner.

This research prioritizes the validity and consistency of data by cross-checking several simulation sessions. The validity and reliability of the data is supported by procedures for comparing results between sessions, so that the conclusions drawn can be relied upon.

In addition, this research complies with research ethics by maintaining the privacy of respondent data and maintaining the confidentiality of information obtained during data collection at FMSS.

The data obtained is only used for the purposes of this research and is not distributed without permission.

Overall, this research strategy is designed to provide a solution to the problem of guiding service effectiveness by analyzing relevant empirical data from realistic simulation environments in FMSS.

3. Results and Discussion

3.1. Research result

3.1.1. Research Study Profile

This research was carried out at the Semarang Maritime Science Polytechnic, using an MV ship model. Sinabung on Full Mission Ship Simulator (FMSS).

The selection of the San Francisco harbor model as a simulation location was designed to replicate real conditions allowing researchers to understand movement command patterns in the context of a large port with heavy traffic flow. Modeling using [1].

Markov Chain helps in predicting the movement command fluctuation patterns required until the ship reaches the finish with engine (FWE) condition, namely the condition where the ship is ready to stop at the dock after being fully controlled by the guide.

3.2. Specific Description of Movement Variables

The main variable in this research is the engine telegraph movement (ETM) command issued during the ship piloting process.

This command includes setting the ship's speed from full ahead (F/A) to full astern (F/As), which aims to adapt the ship to the water conditions around the port.

ETM was chosen because it is an important parameter in assessing the competency and efficiency of guides.

ETM data includes details such as command frequency, time spent in each speed state, as well as state changes from one state to another.

3.3. Amount of Data Used

In this research, maneuver command data was collected through 10 different simulation sessions, with each session requiring several speed changes according [5] to the conditions encountered on each shipping lane.

The observation results from the ship's movement log are then processed into a transition matrix, where each transition is analyzed to obtain probability values between ETM states.

This transition matrix is the basis for analyzing movement patterns and the duration required to reach a steady state in the guiding process.

3.4. Key Research Findings

This research found a number of important points regarding the effectiveness and movement patterns in the guiding process:

3.4.1. Movement Command Patterns

The average number of maneuvering commands required from the pilot station to the dock is around 10 commands. This command includes the use [6] of speed modes from F/A to F/As.

Each command has a certain frequency which varies depending on the conditions faced by the ship in the waters.

3.4.2. Average Duration of Movement Commands

Based on simulation data, the average duration for each command in each state shows significant variations, with the duration in certain states (such as slow ahead) being longer than in other states. For example, to reach FWE conditions, a ship needs around 0.60 hours in moderate weather conditions.

The use of the Markov Chain method allows more measurable predictions regarding the average time required in each speed state.

3.4.3. Transition Probability Between ETM States

Transition probability analysis shows that the full ahead and half ahead states have a higher frequency in the early stages of the piloting process, while the slow ahead and dead slow ahead states are more often used approaching the pier.

The transition probability in steady state conditions shows that around 9.9% of all commands are F/A, while D/A reaches 17.5%, which shows the pilot's preference in slowing the ship's speed when approaching the end point of the maneuver.

3.4.4. Optimal Practice Time for Guide Competency

Based on the simulation results, this study recommends that each pilot undertake at least 8 training sessions in FMSS to achieve a sufficient level of competency in controlling a ship in a port with characteristics such as San Francisco. This is considered the minimum effective training time to reach steady state conditions, with additional training expected to increase the accuracy and responsiveness of exercise commands.

4. Discussion

4.1. Urgency of Research and Problems of Guiding Efficiency

This research is motivated by the urgent need to increase the efficiency of ship pilotage services at ports, which is important to ensure security and punctuality. With the increasing volume of ship traffic, especially in large ports such as the Suwadi [7] San Francisco port model, ship handling requires effective and efficient strategies in managing maneuvering orders.

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This urgency is driven by the need for objective assessment standards to improve pilot competency in a dynamic port environment, especially related to the management of engine telegraph movement (ETM).

Without a standard time, standard, inaccuracy in pilotage can increase berthing time, which ultimately has an impact on overall port efficiency.

4.2. Analysis of Movement Fluctuation Data as an Efficiency Solution

This research identifies fluctuations in maneuvering commands based on MV ship simulation data. Sinabung at FMSS. This data includes a number of ETM commands that the pilot uses under various conditions. Analysis using the Markov Chain method focuses on the transition probability between ETM states, which maps the average duration of each [8] state towards the final steady state or finish with engine (FWE). From the empirical distribution table of maneuvering commands (see Table 1), it appears that the frequency of commands is different for each speed status, which is influenced by current and wind conditions. The average duration for each ETM command, especially in the slow ahead state, tends to be longer to provide maximum control when the ship approaches the dock.

Table 1.
Empirical Distribution of MV Movement Commands. Sinabung.

Date	**ETM command**
02/06	St → F/A → H/A → S/A → D/A → F/A
09/06	F/A → H/A → D/A → S/A → D/A → F/A
...	...
Rate-rate	10 ETM orders in 0.60 hours

This data indicates that the number of movement commands and the duration of each command varies greatly, but with transition patterns that tend to be stable at steady state conditions.

4.3. Comparison with Previous Novelties and Significance of the Study

This approach provides an important contribution to the literature related to ship piloting efficiency which previously did not utilize dynamic ETM data as a performance indicator.

Previously, research on Markov Chains was applied in other sectors, such as student academic streams and agriculture, but has not been widely applied to scouting services.

For example, a study by Alawadhi and Konsowa [3] used the Markov Chain to map academic flows in universities, while Abdurachman [9] applied this method in estimating livestock production time.

This research highlights how the Markov Chain model can be adapted to capture movement command patterns and provide a more measurable standard for assessing piloting competency.

4.4. Potential Impact of More Measurable Assessment Standards

By determining service time standards based on ETM state transition probabilities, ports can set more appropriate performance indicators for scouts [10].

This will increase the accuracy of assessments and can support guide training programs to improve the efficiency and safety of guiding services. Guides who have practiced using this model will have a better understanding of efficient command patterns, which will reduce waiting times and port operational costs.

The long-term effect of this approach is increased productivity and punctuality which will impact the port's reputation in global trade.

4.5. Research Limitations and Suggestions for Further Development

The main limitation of this study is the port model and type of vessel used, which are limited to MV. Sinabung in the San Francisco harbor model.

These conditions may not cover all operational variations at global ports. Therefore, it is recommended that future research involve a wider variety of port and ship models and consider extreme weather variables, such as high waves and strong winds.

In addition, the addition of simulation scenarios for emergencies will provide a more comprehensive picture of the scouts' readiness to face unexpected conditions.

5. Conclusion

This research aims to analyze ship movement command patterns and determine optimal pilotage service time standards using simulation data in the Full Mission Ship Simulator.

The research results show that the pattern of movement commands applied by the pilot has significant variations depending on the conditions in the water, with varying duration at each ship speed to reach the finish with engine (FWE) point.

Through the application of Markov Chain analysis, this research succeeded in identifying transition probabilities between engine telegraph movement (ETM) states, which is useful in modeling more efficient guidance service times.

This study makes an important contribution to the literature regarding improving efficiency and safety in ports through a more systematic analysis of pilotage service times.

These results also offer practical guidance in establishing optimal training duration for novice scouts to improve their abilities.

However, the limitations of this research lie in its attachment to ship models and port conditions which are limited to FMSS simulations at the Semarang Shipping Science Polytechnic, which may not fully represent variations in global port conditions.

Further research is recommended to include different port models and consider extreme weather variables to produce more flexible and widely applicable service time standards.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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