論文の要旨

題 目　BASIC SHIP-PLANNING SUPPORT SYSTEM USING BIG DATA IN MARITIME LOGISTICS FOR SIMULATING DEMAND GENERATION

（ 海上物流ビッグデータを活用した船舶需要創出シミュレーションのための船舶基本計画支援システムの開発 ）

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Economic growth creates dynamic changes in the global market, including the maritime industry. On a worldwide scale, huge demand for industrial cargo transport promotes intense ship movement and replacement. As the demand for newbuilding specifications also changes according to the circumstances, developing a ship with adequate specifications to satisfy this demand is essential.

Meanwhile, the use of digital infrastructure to alter a business model and implement value-producing opportunities naturally generates a large data stream called big data. With the reduction in cost of data collection tools, a large amount of data can be obtained from various sources and formats. This is significant for a broader understanding of the current and future conditions of various industries. Therefore, big data analytics will be a critical advantage in the future.

In the maritime industry, big data are being generated through advancements in navigation systems. Together with the voyage data recorder, an automatic identification system (AIS) is required by the International Convention for the Safety of Life at Sea to aid navigation and avoid collisions of ocean-going ships. Towards its development, the deployment of satellite-based AIS receiver enables an accurate ship's geospatial monitoring on a worldwide scale. From the ship side, an AIS transponder also transmits a ship's identification number, position, course, speed, and destination. These systems uphold the digitalization of previously analog-stored data, such as ship specifications, port limitations, and sailing routes.

The collection of static and dynamic big data in maritime logistics has allowed various studies to be conducted. Safety improvement, energy efficiency, logistics optimization, and predictive analysis have been broadly discussed. Similarly, many data-driven studies have introduced a demand forecasting application for both regional and global scales. Forecasting analyses, such as the cargo throughput and shipbuilding market, have also been presented in some studies; however, the demand for new ship specifications is unlikely to have been covered.

With big data in maritime logistics, ship operation monitoring is becoming relevant. Besides, shipbuilding tends to apply risk-based design rather than rules-based design, with aims of compatibility of design and performance. Likewise, the International Maritime Organization (IMO) greenhouse gas (GHG) reduction strategy set out a new future guideline. Therefore, it is crucial to examine the actual ship operation characteristics in the particular route to optimize its future ship design, both cost- and GHG-effectively.

Our prior studies examined the demand for new ship specifications by proposing a basic ship-planning support system using big data in maritime logistics. The proposed system was applied to the target ship of Capesize dry bulk carrier, which operated on relatively fixed routes, such as Australia and Brazil to East Asia routes. Assuming the target ship operated in a time-charter contract manner, we built an algorithm to replicate its ship bidding scheme. However, the scope of that study was limited by the target routes and ship allocation considerations. The previous system delivered the simulations by only considering the ships' fuel costs; by contrast, this study has proposed an enhancement to our basic ship-planning support system. Additionally, we have broadened the scope to a global scale to understand the ship specifications in demand. Furthermore, we proposed the voyage-charter contract in addition to the assumed time-charter contract scheme. Finally, we suggest two attributes to be considered in the ship allocation algorithm: ship cost (COST) aspects and GHG emissions.

Following what has already been discussed, we developed several models: the global network model, cargo movement model, and ship model. The global network model characterizes each port and route served by the target ships. The Cargo movement model describes the worldwide port-to-port cargo movement demand (CARGO) served by the target ships. The ship model represents individual target ships' data and operation conditions. Further, the results of these models are used as input to the calculations of GHG emissions and COST. The total GHG emissions consist of the GHG emitted from ships' main engine, auxiliary engine, and boiler, whereas the total COST contains the costs of ships' fuel, operation, depreciation, and stockpile.

Further to the calculated attributes of ships toward certain routes, we proposed three discrete algorithms as the ship allocation algorithm following a specific scheme: existing ships replacement by using new ships without changing their allocation, ship allocation optimization in a time-charter contract manner, and ship allocation optimization in a voyage-charter contract manner. Algorithm 1 proposes an optimization by offering a direct clone of the existing ship, a new ship with the exact specifications and operation conditions that serve the same annual allocations. Algorithm 2 reconstructs the ship allocation to transport the cargo movement demand using the offered ships in a time-charter contract manner. Algorithm 3 reconstructs the ship allocation to transport the cargo movement demand using the offered ships in a voyage-charter contract manner. Hence, using the defined algorithm, the following were the objectives of the conducted simulations: Capesize dry bulk carrier (DWT 100,000 or more, 1647 ships), and Panamax–MiniCape dry bulk carriers (DWT 65,000–140,000, 2479 ships), towards the worldwide routes of iron ore, coal, grain, and others in 2018 (routes served by target ship). Finally, we summarized the results graphically in a great circle format.

Furthermore, we conducted discrete simulations in followings case studies intended for: Capesize dry bulk carrier, Panamax–MiniCape dry bulk carriers, and future scenarios of 2030 and 2050. In the case of Capesize dry bulk carrier, we conducted several simulations using algorithms 1 and 2: ship replacement while preserving existing ship allocation (case study 1), optimization of ship allocation using existing ships (case study 2), and optimization of ship allocation using new ships instance (case study 3). First, we analyzed the actual ship allocation to understand the current ship allocation characteristics. Case study 1 analyzed new ships to replace existing ships without changing their allocation. Case study 2 reconstructed the ship allocation using only the existing ships. Case study 3 reconstructed the ship allocation using the existing ships and new ships instance. In the case of Panamax–MiniCape dry bulk carriers, we conducted several simulations using algorithms 1, 2, and 3: ship replacement while preserving existing ship allocation (case study 4), optimization of ship allocation in time- and voyage-charter contracts using existing ships (case study 5), and optimization of ship allocation time- and voyage-charter contracts with new ships instance (case study 6). Lastly, for the purpose of future scenarios, we conducted several simulations using algorithms 2 and 3: optimization of ship allocation time- and voyage-charter contracts with all new ships instance (case study 7). The ship allocation optimization indicated that significant reductions in the total COST and GHG emissions were not achievable using only the existing ships. Using the developed system, we could recreate an operation-level ship allocation considering various scenarios.

Finally, we confirmed the demanded new ship specifications by presenting the new ships instance. However, this study is only feasible for the current constraints of the Capesize and Panamax–MiniCape dry bulk carriers operating in the time- and voyage-charter contract, despite the presented results. The application of the proposed system for the accumulated ship size categories such as Handymax–Capesize dry bulk carriers are considered future tasks.

Likewise, considering the importance of weather routing, the weather correction factor in the main engine's actual power calculation, which was previously assumed constant, is possibly varied. Hence, further studies are crucial to assess the applicability of our system beyond these limitations.