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EDITORIAL

Data-driven optimization and analytics for maritime logistics

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Like many other industries, maritime logistics is more and more driven by optimization and analytics to make the best out of the wealth of data generated through modern technologies. This opens up many research questions in areas such as the operations management of autonomous ships and port equipment, a better understanding of markets through the analysis of demands and price data, new forms of collaborations and many more. Emerging innovations can support all kinds of actors from the maritime logistics industry in making better decisions, reaching higher levels of performance, becoming more sustainable and, eventually, improving their competitiveness. Research has to support and advance this by incorporating and adapting current models and algorithms to assess and explore the impact of novel features and industry innovations. In parallel, investigation related to enhancing and developing

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approaches that use available data and improve current operations regarding valuable decision support is fundamental.

This special issue of the Flexible Services and Manufacturing (FSM) Journal aims to address challenges and explore the opportunities related to maritime logistics from such perspectives. The following nine papers contribute to introducing new concepts, defining new problems, and developing new methodologies and models to exploit the wealth of data generated by the maritime logistics industry.

1 Papers in the special issue

In the paper of El Mekkaoui et al. (2023), deep learning sequence models are proposed to predict vessel arrival times using different data sources, including vessel characteristics, data from automatic identification systems (AIS), and weather data. The authors apply three different sequence models based on a recurrent neural network and two convolutional neural networks, and compare them with a non-sequence multilayer perceptron (MLP) based model. Experiments are conducted using data from the Jorf Lasfar Port in Marocco and reveal that the sequence models outperform the non-sequence model. The Long Short Term Memory (LSTM) based recurrent neural network shows the best performance. The authors explain that by the ability of sequence models to incorporate past information in the prediction.

Kolley et al. (2023) study the berth allocation problem where uncertainty in vessel arrival times, e.g., due to weather, is taken into account. In order to achieve robustness, they apply four different Machine Learning methods to predict vessel arrival times. It is shown that these can provide good forecast accuracy, which leads to both more robust solutions and less actual waiting times for the vessels. Moreover, it turns out that the accuracy of the resulting berthing schedules, measured as the deviation of planned and actually realizable schedules, exceeds the accuracy of all forecasts.

The paper of van der Steeg et al. (2023) proposes a procedure for real-time disruption recovery of berth plans. The authors present a decision model for generating a cyclic baseline berth plan. This model respects tidal windows for the calling ships as well as repeated visits of the same shipping line on a regular basis. The authors then provide a series of re-planning methods for a quick recovery of the berth plan when disruptions occur. The conducted experiments reveal that a disruption recovery method involving Constraint Programming techniques performs best in most cases.

Algendi et al. (2023) consider a maritime inventory routing problem (MIRP) with load-dependent speed optimization. This problem involves determining optimal routes, loading/unloading quantities and sailing speeds along these routes, while respecting inventory limits in a set of production and consumption ports. In contrast to the normal situation where production levels are given as input to the problem, they treat these as decision variables. Computational experiments on a set of benchmark instances from the literature show that including the production decisions in the MIRP can significantly reduce transportation costs.

The paper of Cammin et al. (2023) provides a framework to create portrelated vessel air emissions inventories (EIs). This research is motivated by the fact that a significant number of ports do not provide EIs of visiting ships due to the high costs of obtaining data. The authors apply artificial neural network (ANN), multilinear regression (MLR), and support vector regression (SVR) to predict vessel EIs based on vessel data. They find that some machine learning models provide a similar performance while requiring less data. This study sheds light on the trade-offs between the prediction performance of machine learning models and costs of data, promoting the use of EIs for sustainable shipping.

Park et al. (2023) address the real-time location of containers within container terminals. To address this problem, the authors present a two-modulebased decision support system that permits managing the underlying container stacking problem. The first module generates a group-specific container weight classification using predictive analytics. The second module uses an online algorithm to determine the storage location employing a dynamic category stacking strategy. Numerical experiments consider real-life data from a container terminal in Korea and alternative stacking strategies, including current practice. The results show that their proposed approach performs better than the alternative strategies and can further result in better terminal competitiveness. In this regard, they show that the improvements in the stacking performance are related to category stacking.

The paper of Karakaya et al. (2023) proposes an analytical model to optimize the layout of empty container depots aiming to minimize cycle times of top-lifters (TLs). The model respects travel times of TLs using geometry and retrieval/placement times based on a Markov chain model using empirical data from a typical empty container yard. The authors present results for rectangular and non-rectangular shaped container yards and indicate that the rectangular layout is more efficient than L-shaped designs due to lower relocation and placement times.

Fontes and Homayouni (2023) address the joint scheduling of quay cranes and speed-adjustable vehicles at container terminals to reduce energy consumption and makespan. Given the bi-objective nature of the problem, the authors develop a bi-objective biased random key genetic algorithm with multiple populations (mp-BRKGA). The MILP model is solved using a combination of ϵ-constraint and lexicographic methods. Results show that the MILP and mpBRKGA exhibit a compelling performance in small instances. Moreover, when the problem's size grows, mp-BRKGA can provide diverse and uniformly distributed solutions. By analyzing results, incorporating speed-adjustable AGVs increases management flexibility since it results in a broader range of trade-off solutions concerning energy consumption and makespan.

The work of Li et al. (2023) extends the Liquefied Natural Gas problem with Annual Delivery Program (LNG-ADP) by incorporating transshipment and waiting at customer ports. The problem is modeled by a novel discrete-time formulation, and due to its size, a rolling horizon heuristic (RHH) is proposed as well as heuristic rules and branching strategies. The authors assess their approach using a case study based on Yamal LNG and new problem instances. Results over different configurations of RHH indicate that the myopic configuration provides good results at the expense of longer computational times. Furthermore, the authors point out that increasing forecast duration can reduce RHH computational times while increasing solution quality. Lastly, although introducing waiting times does not necessarily improve solutions' quality, it results in an overall reduction in runtime compared to when it is not allowed.

2 Concluding remarks

We congratulate all authors to their excellent research and we thank all reviewers for their helpful comments and their timely refereeing.

References

Algendi A, Urrutia S, and Hvattum LM (2023) Optimizing production levels in maritime inventory routing with load-dependent speed optimization. Flex Serv Manuf J

Cammin P, Yu J, Voß S (2023) Tiered prediction models for port vessel emissions inventories. Flex Serv Manuf J

Fontes DBMM and Homayouni SM (2023). A bi-objective multipopulation biased random key genetic algorithm for joint scheduling quay cranes and speed adjustable vehicles in container terminals. Flex Serv Manuf J.

Karakaya E, Smith AE, Ramírez, RGG, and Pascual J (2023). Design of empty container depot layouts using data and analytics. Flex Serv Manuf J

Kolley L, Rückert N, Kastner M, Jahn C, and Fischer, K (2023). Robust berth scheduling using machine learning for vessel arrival time prediction. Flex Serv Manuf J

Li M, Fagerholt K, and Schütz P (2023) Maritime inventory routing with transshipment: the case of Yamal *LNG*. Flex Serv Manuf J

El Mekkaoui S, Benabbou L, and Berrado A (2023) Deep learning models for vessel's ETA prediction: bulk ports perspective. Flex Serv Manuf J

Park HJ, Cho SW, Nanda A, and Park, JH (2023). Data-driven dynamic stacking strategy for export containers in container terminals. Flex Serv Manuf J

van der Steeg JJ, Oudshoorn M, and Yorke-Smith N (2023) Berth planning and real-time disruption recovery: a simulation study for a tidal port. Flex Serv Manuf J