Tramp Shipping Optimization: A Critical Review

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Abstract

The purpose of this review is to summarize the existing literature on tramp shippingas to explain the current state of understanding on the optimization approaches adopted in such discipline. The review comes with critics to the current literature of tramp shipping optimization to guide the researchers where to go. One such criticalreview is in the operational planning of cargo mix selection. Currently, the optimal cargo mix is the one who contributes more to a grossprofit objective, assuming deterministic cargo transport demand. Since time varies considerably from one alternative ship voyage to another, a research work now exists which considers this objective less profitable than gross-profit-perday objective, assuming both deterministic and stochastic cargo transport demand. The cargo mix should be selected because of the higher gross profit it is expected to yield and the less number of days it takes to generate such profit. Another critical review is in the tactical planning of allocating ships to cargo trade areas. A research work now exists which considers the optimally allocated fleet to cargo trade areas as representing the cargo transport demand in these areas. Planner of utilities in a cargo trade area such as ports, canals, and straits can re-optimize this allocation in different what-if scenarios to fix prices of utility services; e.g., different cargo freights and quantities. A third critical review is in the strategic planning ofappraising new ships. A research work now exists which considers the new ship as a fleet unit when the fleet is optimally allocated to cargo trade areas. The gross profit and other cash flow items of the new ship can then be identified for each year of its lifetime. Three net present values can be generated: one for optimistic,most likely, and pessimistic cargo-transport demand forecast.

Index terms— optimal cargo mix; transportation scheduling; transportation routing; transportation allocation; transportation appraisal.

1 Introduction

f compared to other businesses, cargo transportation in tramp mode has three distinctive characteristics.

The first characteristic is that its production cycle (ship voyage) passes through different economic systems which cause uncertainty and create unstructured decision situation (Fields and Shingles, 2016). In an unstructured decision situation, solution steps are usually not known beforehand. The second characteristic is that production time (voyage time) varies considerably from one alternative production cycle to another. The production cycle is said to be time-sensitive because of this variation in time. The variation is mainly caused by the alternative cargo mixes available for transport in competition with other ships, the alternative shipping routes the ship may follow

Author: e-mail: selnoshokaty@elesteshary.com towards the same cargo mix, and the alternative ship speeds at which the ship may sail. In comparison, the production cycle in liner shipping is not sensitive to time since production time is fixed where the ship sails per a predetermined itinerary (see El Noshokaty (2013)). Likewise, crop harvesting in agriculture, car manufacturing and assembly lines in industry and road paving in construction are all time-insensitive. Timesensitivity is known to the ship-owner when he hires his ship as a time charter for a better hire per-day. Main while he ignores it when he does not hire his ship as a voyage charter for a better gross profit per day (Time Charter Equivalent rate in voyage charter is not the gross profit per day as been defined in this paper). However, the ship owner shows awareness of time sensitivity when he puts in the voyage charter party a clause specifying a minimum cargo loading and time. This action influences few cost and revenue items plus cargo handling days, while a gross-profit-per-day objective influences all cost and revenue items plus all voyage days, including sailing and waiting days. The gross-profit-per-day objective is more described afterward. The third characteristic is that transportation unit calls at a variable number of stops and follows many calling sequences among these stops. In other words, a transportation unit does not operate on a published schedule but serves different stops in response to tenders of cargo. It runs like a taxi cab in private transport if compared to a bus in public transport. This mode of operation requires, in model terminology, many variables and constraints which in turn requires the use of mathematical models (Christiansen and Fagerholt, 2014).

If one thinks of a solution methodology to solve tramp transportation problems, he must overcome three main problems; one for each business characteristic mentioned earlier. The first problem is the uncertainty or randomness in factors affecting the business. There should be a stochastic formulation by which one can explore future cargo transport demand. Knowing this demand will help owners of transportation units making more sound unstructured operational decisions. It might be better to consider a cargo expected to be offered I discharging rate. His intention is to minimize the voyage rather than one that is offered if the former will most likely contribute more towards gross profit (the term 'offered' refers to a confirmed shipping proposal, while 'not-yet-offered' refers to unconfirmed shipping proposal). The second problem is the use of a grossprofit-per-day objective, rather than a gross-profit one; since time varies considerably from one alternative ship voyage to another. Gross-profit-per-day objective cares for the higher gross profit it yields and the less number of days it takes to generate such profit. To explain, assume there are two cargoes and one must choose only one: cargo A which yields a gross profit of $ 2 million in 200 days ($ 10,000 per day), and cargo B which yields a gross profit of $ 1.5 million in 100 days ($ 15,000 per day). Although cargo B generates less gross profit, it causes the transport-unit owner to get $ 3 million in 200 days instead of $ 2 million, if the owner highly expects that shippers will offer B-like cargo after the 100 days. To account for such expectation, the gross-profit-per-day objective must have a stochastic formulation to incorporate future transport demand as what has been mentioned earlier. In comparison, the current practice of ship owners is to choose cargo A with a Time Charter Equivalent rate of $ 10,000 per day. The third problem is the need to explore massive alternative solutions before reaching the optimal solution. Fortunately, Operations Research (OR) techniques provide such solution methodology. The impact of the optimal solution provided by OR on any logistics and supply chain system is that it maintains the shortest possible transportation time owners of transport units can afford. The challenge in using OR models is in including all the necessary parameters and business rules that represent a real cargo transport problem. And, because some of these parameters are fixed, they need to be checked for validity. Also, OR models have to be incorporated into a decision support system to allow non-OR users to deliver model parameters, and to run and interact with these models.

2 II.

3 Review Summary

The introduction in Section one lays the ground needed to establish the review elements needed to evaluate the papers in the current tramp shipping literature. In the operational planning, the current research papers are used to select the cargo mix based on the contribution it adds to the gross-profit of each transport unit, assuming deterministic transport demand for each cargo, while the gross profit per day and randomness of cargo demand are two important issues in tramp shipping not to ignore. The models in such papers do not present real shipping elements and rules; 20 such elements and rules, all affect profitability, are discussed in El Noshokaty (2017a). If these research papers use OR-based models, users of these models must acquire additional skills related to OR. In contrast, decision support systems have OR models built-in. Finally, current research papers usually do not check for validity of model parameters, especially cargo quantity and freight, cargo handling rate and charges, and ship speed and fuel consumption. Sensitivity and what-if analysis, which are usually used to check such validity, do not appear in any of these research papers.

In the tactical planning, the current research papers are used to allocate the fleet units to cargo trade areas based on an objective function of cost items only with restricting assumption on a) cargo transport demand to be large enough, b) restricting assumption on ship working condition to be limited to one area, and c) restricting assumption on shipload to be limited to one cargo. An innovative research work now exists which uses the optimal gross profit generated for each ship voyage completed on each trade area to allocate the fleet units to trade areas. The calling frequency can then be specified for each unit on each trade area. While the operational planning cares for the alternative production cycles caused by the alternative cargo mixes ready to be transported within a short-term planning period, the tactical planning cares for the alternative production cycles caused by the alternative trade areas ready to be serviced within a long-term planning period. Each trade area has its characteristics of commodity type, quantity and freight of cargo, service cost, and sailing distance. Several applications of this allocation now exist in the literature. One useful application of this allocation is to consider the frequency of calls as representing the demand for services rendered by utilities operating in each trade area. Another useful application is to include, in a competitive environment, the new ships along with the old ones in the allocation plan to find the share each new ship adds to total gross profit each year. The new ship gross profit can be used along with other cash flow and cost of investment, to calculate the net present value of this new ship. Three net present values can be generated: one for optimistic, most likely, and pessimistic cargo-transport demand forecast.

The term 'tramp shipping optimization' refers to the use of OR to maximize revenue or minimize the cost of a tramp shipping problem, subject to the limited shipping resources. In the following sections, the current research papers are critically reviewed. Section 3 reviews the papers classified as 'optimization of the ship voyage,' Section 4 reviews the papers classified as 'voyage sensitivity and what-if analysis,' Section 5 reviews the papers classified as 'optimization of the ship allocation,' and Section 6 reviews the papers classified as 'new ship appraisal.' Section 7 concludes the review and brings some suggestions for the future research work.

4 III.

5 Optimization of the Ship Voyage

One tramp shipping problem exists when there are some ships and some cargoes, and it is required to find out the cargo mix assigned to each ship voyage which maximizes total gross profit per day for all ships, subject to ship capacity and cargo time window (lay can). To give more details on this research area, consider the following facts. Unlike 'optimization in liner shipping,' both ports of call and port calling sequence are here assumed optional. Charter party, signed by the ship owner and the charterer, usually specifies terms and clauses to be followed by both parties. Non-demise voyage charter parties are assumed here. Terms include the following items: calling ports, calling sequence, cargo freight, cargo time window (lay can), permissible cargo handling time (lay days), dispatch count if actual days are less than lay days, and demurrage count if more. Loading and discharging lay days may be considered in reversibly or irreversibly manner. If reversible, lay days are specified for loading and discharging collectively. If irreversible, lay days are specified for loading and discharging separately. The gross terms of voyage charter party are here assumed unless otherwise specified. Before cargoes are being fixed by the ship owner, 'optimization of the ship voyage' helps in proposing a voyage plan suggesting an optimal cargo mix for each ship. This mix maximizes the sum of voyage gross-profit-per-day for all ships, subject to ship capacity, cargo lay-can, and other voyage charter party terms. In the cargo mix selection, the random nature of sea transport demand has to be considered.

What is mentioned above describes the original problem in tramp shipping. In turning some or all the characteristics of 'optimization of the ship voyage' referred to in this problem into an OR model, the following research efforts were cited. A general review is given by Christiansen et al. (**??**004), Christiansen et al. (2013), and Christiansen and Fagerholt (2014). Appelgren (1969Appelgren (, 1971) addressed the problem of tramp shipping for a fleet of cargo ships. The problem of these research papers is to assign an optimal loading sequence of cargoes to each ship during a given time. Each cargo has a loading time window, size, type, port of loading, port of discharge, and cargo handling time in these ports. Each ship has its operational characteristics of the initial position and the expected daily marginal revenue of optional cargoes which may become available during the planning period. All contracted cargoes must be loaded, whereas optional cargoes may be accepted or rejected. A ship may carry only one cargo at a time. The objective is to maximize the revenue of optional cargoes minus cargo handling and fuel cost. The review of these research papers is reported in the follows items. The first is that their research model is most useful for bulk carriers since it assumes only one cargo to be loaded at a time. The second is that the problem known in the literature as the 'fixed-charge problem' is not addressed. In this problem, fixed charges; such as port dues, are to be paid no matter how many cargoes ship selects in each port. The third is that the objective does not consider the time taken to earn revenues. In tramp shipping, revenue or gross profit per day is a common objective.

Bauch, Brown, and Ronen (1998) and **??**erakis (1992a, 1992b) have put emphasis on application and implementation using an OR model not much different than that of Appelgren. The authors have captured raw data about cargoes, ships, ports, and distances and use it to generate all possible schedules for each ship. Each schedule identifies several cargoes to be transported, arranged and put in a predetermined sequence. Data about these schedules is input to an integer programming package as package parameters. The package was run to select the set of schedules that gives an optimal solution. The same review mentioned about Appelgren also applies here, plus the fact that the generation of all possible schedules is not guaranteed. Fagerholt (2001) has developed an optimization model for tramp shipping, where cargo time window (lay can) may be violated to a certain extent with a penalty cost in return. That is why cargo time window was given the name soft time window, and penalty cost was given the name inconvenience cost. The model designs a predetermined set of schedules for each ship to follow. In each schedule, there is a predetermined route with cargo pick-up and delivery nodes along with soft time window for each node and a predetermined ship speed on each sailing leg. The model objective is to find the schedule for each ship which minimizes total operating and penalty cost. The review of this model is reported in the follows items. The first is that the number of schedules of each ship is too small to represent all candidate schedules. The second is that even if the number of schedules is large enough, the way the schedule is designed does not generate a right mix between low and high-cost schedules. The right mix has to be the one that leads to a globally optimal solution. The third is that the model does not use gross profit or gross profit per day as a criterion for selecting optimal schedules, which limits the use of the model to only the industrial mode of transport. The fourth is that transport demand is assumed fixed. Fagerholt (2004) has also developed a computer-based decision support system for fleet scheduling based on heuristic algorithms. Fagerholt et al. (2010) have presented a decision support methodology for strategic planning in tramp and industrial shipping. The proposed methodology combines simulation and optimization, where a Monte Carlo simulation framework is built around an optimization-based decision support system for shortterm routing and scheduling. Although these research papers have developed algorithms which are flexible, allow interactive user interface, and save time, their exact optimal solution is not guaranteed.

6 Brown et al. (1987) have developed a

scheduling model for ocean transportation of crude oil. In this model, a schedule represents a ship when assigned the transportation of cargo between its loading port and discharging port. The model aims at minimizing total cost of schedules for all ships. It uses an Elastic Set Partitioning algorithm. The review of this model is reported in the follows items. The first is that cargo loading or discharging time window is not considered. The second is that ships are assumed to have similar capacity. The third is that full ship loads are assumed. The fourth is that consecutive loads are not allowed because the planning period is too short to accommodate more than one ship voyage. The fifth is that the model does not use gross profit or gross profit per day as a criterion for selecting optimal schedules. The sixth is that transport demand is assumed fixed. Kim and Loe (1997) have developed a decision support system for ship scheduling in industrial bulk trade. The solution method is similar to what is given by Brown et al. **??**1987).

Lin and Liu (2011) have considered the ship routing problem of tramp shipping and proposed a combined mathematical model that simultaneously takes into account the ship allocation, freight assignment and ship routing problems. To solve this problem, they have developed an innovative genetic algorithm. The review of this model is reported in the follows items. The first is that multi-commodity concept considered by this model is reduced to maximum one primary cargo, and one spot cargo was taken one after the other by any ship voyage. The second is that the model does not use gross profit per day as a criterion for selecting an optimal solution. The third is that transport demand is assumed fixed.

Laake and Zhang (**??**013) have developed a model to determine the best mix of long-term and spot cargo contracts for a given fleet. The model finds the optimal fleet size and a mix for a set of cargo contracts or a mix of both. The model assumes that transport demand is sufficiently large on each route. Each ship takes full loads and does not mix cargoes from different cargo contracts, which is standard practice in the coal/iron ore trade. The review of Lin and Liu paper applies here also.

It was found that the OR model of Osman et al. (1993) and Christiansen et al. (2007) holds characteristics close to the tramp shipping characteristics mentioned at the beginning of this section. The model of either research is based on a network of multiple cargo flows. Each network node either represents a load or a discharge event for each cargo. Ships are competing in carrying cargoes by following selected arcs in the network, beginning with a start node and ending with an end node. If a network arc is used by a ship, this arc is restricted for use by other ships. An arc is used by a ship if lay can of each arc node be met and load available in each arc node is within remaining ship capacity. The model assigns network arcs to ships in an attempt to maximize total voyage-gross-profits for all ships. Both models are nonlinear. Hemmati et al. (2014) The first is that the model objective maximizes voyage gross-profit, while in tramp shipping the objective has to maximize gross profit per day. The second is that transport demand is assumed deterministic. In shipping, some cargoes may have random demand. The third is that the model with non-linear objective or/and constraints call for software solutions usually less reliable and inefficient. The fourth is that the authors brought no evidence on the possibility of solving large problems when more cargoes and ships are added. Bakkehaug et al. (2016) and Vilhelmsen et al.

(2017) have developed a similar model to schedule the voyages of a fleet of ships considering a minimum time spread between some voyages. The former has used the Adaptive Large Neighborhood Search (ALNS) heuristic to solve the problem, while the latter has used a Decomposition approach with Dynamic Programming algorithm for column generation. Their model focuses on the time spread between voyages in response to a charter party clause which requires the voyages to be 'fairly evenly spread.' This requires the voyage to become the model decision variable with a predetermined route and full-load cargo to be transported in each voyage. This situation might be true for some contracted cargoes, but not true otherwise. Therefore, these two research papers cannot stand as 'optimization of ship voyage' research area as defined earlier.

There are three additional review items which cut across all research papers mentioned so far. These items can be summarized as follows: This review of the literature on 'optimization of the ship voyage' and the review items brought about it reveals the fact that research papers are in common attempting to solve the original problem mentioned at the beginning of this section but with different review comments. Review comments can be summarized in using a model with deterministic gross profit objective, with little shipping elements and rules, with no checks deliver data and to run and interact with the model. This review gives rise to the contribution made by El Noshokaty (2017a, 2017b), namely, the development of an OR-based decision support system which can optimize the ship voyage outcome considering all possible shipping elements and charter party clauses, gross-profit-per-day objective, deterministic and stochastic cargo transport demand, and sensitivity and what-if analysis. The use of gross-profit-per-day objective under deterministic and stochastic cargo transport demand, assuming multiple ships carrying various cargoes simultaneously along with realistic and validated shipping elements and rules, is presented in

The following is a basic version of the linear optimization model of tramp shipping developed by El Noshokaty (2017a). The model contains the objective function, flow constraints, capacity constraints, time constraints, and non-negativity and integrality constraints. The objective function is expressed in a total voyage-gross profits-per-day for all ships. The flow constraints connect selected cargo transport links of each ship from voyage beginning to voyage end. They also ensure the flow of at most one transport link towards each cargo. The capacity constraints ensure the ship capacity; expressed in weight, is not violated by the cargo mix selected in each transport link. The time constraints ensure the time window allowed for loading or discharging of each cargo is not violated by the time spent in ports and sailing towards the cargo. They also calculate the ship waiting time spent before the opening time of each cargo time window. The non-negativity constraints ensure the model variables do not go negative. The integrality constraints turn the variables, dedicated for the transverse of transport links to yes-orno decisions.

In this model let: ?? = {1,

7 Flow Constraints

Using the above-mentioned denotations, the flow constraints can be formulated as follows: ? The flow constraints which restrict the flow of transport links for each ship originating from open event to only one link at most, given by:

(

? Flow constraints which restrict the flow of transport links for each ship towards event ?? ? ?? to be equal to the flow of transport links outward from this event, given by:

(

? Flow constraints which restrict the flow of transport links for each ship towards load event ?? ? ?? of cargo ?? ? ?? to be equal to the flow of transport links towards discharging event ?? ? ?? of same cargo, given by: (

? Flow constraints which prohibit the flow of transport link of each ship in two opposite directions, given by:

(

? Flow constraints which restrict the flow of transport links of all ships towards loading event ?? ? ?? of cargo ?? ? ?? to only one at most, given by: (

8 Capacity Constraints

Let:

???? be weight of cargo ?? ? ?? at event ?? ? ??, in mt, ?? ?? ?? be the remaining dwt capacity of ship ?? ? ?? after load or discharge of cargo ?? ? ?? at event ?? ? ??, in mt, ?? ?? be the dead weight capacity of ship ?? ? ??, Using the above-mentioned denotations, the capacity constraints can be formulated as follows: ? Load remaining weight constraints which restrict remaining weight on board each ship at end event ?? ? ?? to be at least equal to remaining weight at start event ?? ? ?? of any transport link minus weight of cargo ?? ? ?? at ?? ? ??, given by: (

Constraints (7) can be re-written as follows:

M

9 Non-Negativity and Integrality Constraints

? Non-negativity constraints of continuous variables, given by: (

? Integrality constraints of integer variables, given by: (

The chance-constrained (stochastic) version of the above-mentioned model can be described using the following simple denotations, assuming one ship and one cargo. The transport demand of this cargo is unconfirmed, assumed to be random variable having a known probability distribution. The probability distribution is the marginal distribution of demand.

10 Let:

?? be the deterministic cargo transport demand, expressed in quantity units, ?? be the random cargo transport demand, expressed in quantity units, ?? be the least probability ship owner stipulates to transport cargo within ??, ?? be the quantity of cargo to be transported. Transport demand constraint implied by the model is given by:?? ? ??,**(17)**

In chance-constrained model this constraint reads: the probability of transporting cargo within demand; Prob. {?? ? ??}, has to be greater or equal to ??, as indicated by:Prob. {?? ? ??} ? ??,**(18)**

Constraint (18) is called 'chance-constraint'. If at ?? = d the descending cumulative probability of transport demand of cargo has a value just greater or equal to ??, then (18) in this case implies:?? ? d (**19**)

As defined earlier, the chance-constrained model is exactly (1) to (16) after converting implied constraint (17) to (19).

The model may be solved by **??**lock 19) is the deterministic-equivalent constraint to (18). It is different from constraint (17) in that ?? is the quantity of cargo r confirmed offer, while d in (19) is a deterministic-equivalent quantity of cargo random demand, as described earlier.

11 Voyage Sensitivity and What-if Analysis

Unlike other research papers, the programming algorithm used to solve the optimization model in El Noshokaty (2017a), permits the user to change the model parameters after optimization without the need to re-optimize it from the beginning. This option permits the ship owner to easily change parameters such as cargo freight rate and quantity, cargo handling rate and charges, and ship speed and fuel consumption, in an attempt to see the effect of this change on the optimal solution. This option also permits the user to validate the model parameters. In the sensitivity analysis, series of changes are given to the model to see how far these changes are effective. In what-if analysis, a single change, in an interactive mode, is input to the model to see the effect of this change on the objective function. Speed sensitivity or what-if analysis may be applied to all transport links collectively, or to selective transport links separately.

12 V. Optimization of the Ship Allocation

Another problem in tramp shipping also exists when there are some ships and some trade areas, and it is required to allocate these ships to these trade areas, in an attempt to identify which trade area best fits the characteristics of each ship. The objective would be to maximize fleet gross-profit, subject to available cargo demand in each trade area and yearly working days for each ship. It goes without saying that this area of research is of a tactical planning nature, compared to the research area of Section 3 which is of an operational planning nature. On 'optimization of the ship allocation' research area, the following research efforts were cited. Tsilingiris (2005) addressed the problem of optimal allocation of ships to shipping lines in liner shipping, which is applicable also to tramp shipping. Two models, published by **??**erakis (1991a, 1991b) and Powell and Perakis (1997), were used by Tsilingiris to allocate numbers of ship types to the routes developed in his model. The objective is to find the optimal allocation of ships to routes that minimizes total operating and lay-up cost. There are two review items on these research papers. The first is that voyage revenue is assumed fixed, either because cargo mixes are not considered, or cargo transport demand is assumed deterministic. This means that revenue is supposed to have no effect on the ship voyage and the allocation of ships to lines, which is not true. The second is that allocation is done to the number of ships of each ship type, rather than the number of voyages of each ship. Allocation by the number of ships does not permit a ship to work on different lines.

Christiansen et al. (2007) and Fagerholt and Lindstad (2000) discussed an allocation model to allocate voyages of heterogeneous ships to shipping routes. The objective is to find the optimal allocation of ships to routes that minimizes total operating cost plus fixed cost. There are three review items on these research papers. The first is that voyage revenue is not included in the model objective, ignoring the effect of revenue on the allocation. The second is that ship fixed cost is associated with the use of the ship. If the ship is laid up (not used), its fixed cost is going to disappear from the objective function. The third is that the model puts a maximum number of voyages for each ship in the planning period. This number is put on the total number of voyages completed by the ship on all routes. Since voyage days are not equal among routes, this number is difficult to calculate.

Vilhelmsen et al. (2015) explore the tank allocation problem in bulk shipping and devise a heuristic solution method that can find feasible cargo allocations. The method relies on a greedy construction heuristic for finding feasible allocations and local search for improving initially constructed allocations.

The above-mentioned review of the literature on 'optimization of the ship allocation' and the review items brought about it give rise to the contribution that has been achieved by El Noshokaty (2017a). That is, the development of a decision support system which can optimize ship allocation with an objective function of profit items rather than cost items only and without the following limitations: a) restricting assumption on cargo transport demand to be large enough, b) restricting assumption on ship working condition to be limited to one area, and c) restricting assumption on shipload to be limited to one cargo. It is important at this point to differentiate between the tramp-problem names used in this research paper; namely 'optimization of the ship voyage' and 'optimization of the ship allocation,' and the name used in tramp shipping literature as 'tramp ship routing and scheduling problem.' The former names represent an arbitral breakdown of the planning process when compared with that of the latter name. The name 'optimization of the ship voyage,' which implies both the scheduling and routing processes, cares for the alternative production cycles of the same ship caused by the alternative cargo mixes available for transport. It is given to cargo mix selection made in a short term plan, say three to four months at most (as in any ship voyage). Whereas the name 'optimization of the ship allocation,' which implies the routing process only, cares for the alternative production cycles caused by the alternative trade areas available for service. It is given to allocating ships to trade areas in a long-term plan, say one year at least as in budgeting). 'Optimization of the

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F ship voyage' for a long-term plan is not advised, where scheduling process is practically impossible to realize. The reason is that short-term plans, overlapped dynamically, care for varying and detailed shipping elements and rules. Long-term plans, like macro plans, care for aggregated elements and rules. These plans enable handling of many ships and cargoes, which short-term plans with detailed elements and rules cannot accommodate without too many complications. And if accommodated, optimization cannot be done in a reasonable amount of time.

The following is a basic version of the linear optimization model of ship allocation developed by El Noshokaty (2017a). The model allocates existing ships to cargo trade areas and to determine the yearly frequency of calls each ship completes in each area and the ship lay-up days if there is an over capacity. The model contains an objective function, time constraints put on total days spent by each ship each year on all trade areas, quantity constraints put on total weight of cargoes carried by all ships in each trade area each year, and non-negativity and integrality of model variables. The objective function equals to yearly fleet In this model, let: ?? = {1,2,3, ? , ?? 0 } be the set of shipping trade areas. A trade area describes a sea trade between ports in a given geographical place, ?? = {1,2,3, ? , ?? 0 } be the set of ships of single ship type, or multiple ship types if more than one type competes in carrying same cargo, ?????? be the number of days spent in a most-likely voyage ???? be the deadweight of ship ?? ? ??, in metric ton (mt), ???? be the fixed cost per day of ship ?? ? ??, ???? be the yearly working days available for ship ?? ? ??, in number of days, ???? be the yearly max quantity available as cargo demand (including contracted cargoes) on trade area ?? ? ??, in mt, ???? be the yearly min quantity available as contracted cargoes on trade area ?? ? ??, in mt, ð ??"ð ??"???? be the most-likely voyage gross profit ship ?? ? ?? earns on trade area ?? ? ?? (provided by SOS Voyager), ?????? and ???? be the problem decision variables; ?????? be the frequency of calls to be completed by ship ?? ? ?? on trade area ?? ? ?? per year, and ???? be the lay-up days of ship ?? ? ?? per year.

It is required to find the values of ?????? and ????, where ?? ? ?? and ?? ? ??, which maximize total gross profit, given by: (20) Subject to the following constraints: ? Time constraints put by ship yearly working days on total days spent by each ship on all trade areas, given by: (

? Quantity constraints put on total weight of cargoes carried by all ships in each trade area each year, given by: (

? Non-negativity and integrality constraints, given by: (

The model may be solved by the well-known Mixed Integer Continuous Linear Programming algorithm.

The contribution made in this model is in the formulation of the objective function so that it represents a gross profit rather than mere cost items. The contribution is also in the use of gross profit generated from another integrated system dedicated for the optimization of the ship voyage, assuming realistic cargo transport demand, deterministic or stochastic, available on each cargo trade area. In this model, each ship can work on more than one trade area and load more than one cargo. The model may always roll back to the optimization-of-the-ship-voyage model in case its parameters are subject to change. In this case, another session of the optimization-of-the-ship-allocator model is tried. It goes without saying that the more model parameters are truly representing all possible maritime logistics, the more rigorous is the demand assess on port services. **??**odel

15 New Ship Appraisal

The third problem in tramp shipping also exists when there is a need to appraise a new ship; a ship to be built, purchased, or chartered-in. This area of research is of a strategic nature if compared to the two areas mentioned under sections 3 and 5.

gross profit minus cost of fleet lay-up days. The grossprofit-per-day objective is not considered here because the planning period is fixed for one year. shipping. For stochastic cargo transport demand, the optimization-of-the-ship-voyage model can calculate a voyage gross profit corresponding to demand upper limit (best case scenario), deterministic-equivalent value (most likely case), and lower limit (worst case). The three values of gross profit are passed to the optimization-of-The optimization-of-the-ship-voyage model permits the ship owner to change model parameters after optimization without the need to re-optimize it from the beginning. This arrangement allows the ship owner to validate the model by changing parameters such as cargo freight rate and quantity, port cargo handling rate and charges, and ship speed and fuel consumption, to see the effect of this change on the optimal solution. When a new ship is appraised, the model calculates the gross-profit-per-day for each voyage completed on each trade area, along with sensitivity and what-if analysis of cargo quantity and freight. Since new-ship appraisal model cares for futuristic values of its parameters, stochastic rather than deterministic cargo transport demand is considered, especially in the case of tramp shipping. Three sensitivity and what-if analysis levels are identified for the stochastic cargo transport demand: an upper limit, a deterministic-equivalent value, and a lower limit.

The following is a basic version of the new-shipappraisal model developed by El Noshokaty (2017a). In this model, let: ?? 0 = {1,2,3, ? , ?? 0 } be the common set of years of any new ship life time, ?? = {1,2,3, ? , ?? 0 } be the set of new ships, ?? = {1,2,3} be the stochastic cargo transport demand index, where J = 1 if net present value is based on upper limit, J = 2 if based on deterministic-equivalence, and J = 3 if based on lower limit of the stochastic cargo transport demand.

where:

?? ???? ?? = ð ??"ð ??" ???? ?? ? ?? ???? , and ???? = 1 + ???? + ?? VII.

16 Concluding Statement

This concluding statement is to bring about the contribution made in the literature which announces a new policy to all systems which are sensitive to time. In tramp cargo transportation, as an example, the current policy is to select for each transport unit the cargo mix which contributes more to a gross-profit objective, assuming deterministic cargo transport demand. Since tramp cargo transportation system is sensitive to time, where time varies considerably from one alternative ship voyage to another, a new policy introduced in Section 3 and Section 4 would consider this objective as less profitable than gross-profit-per-day objective, assuming both deterministic and stochastic cargo transport demand. Owners of tramp transportation systems should worry not only about gross profit they expect to earn but also about the time taken in earning this profit. To introduce this new policy, a suite of decision support systems is developed by El Noshokaty (2017a) to optimize tramp shipping operations using a stochastic gross-profit-per-day objective. The analysis given by El Noshokaty (2017a) demonstrates the case where the deterministic gross-profit objective is considerably less profitable for tramp shipping than that given by the stochastic gross-profit-per-day objective.

Therefore, the following new management policy is set: a) Use a gross profit per day objective, rather than a gross profit only. b) Consider a deterministic and stochastic cargo transport demand, rather than a deterministic demand only. c) Apply optimization methods and use sensitivity and what-if analysis to validate the optimal solution. In other words, old management policy of using gross-profit objective is not advised anymore, even if stochastic transport demand is absent. In case the probability distribution cannot be identified for cargo transport demand, sensitivity and what-if analysis of cargo quantity and freight can be used with the grossprofit per-day objective.

17 ? ?

? = ? ? ? ? ? ? ? ?? ? ? ? 0 ? ? ? 0 , ? ? ? ,? ? ? ,

The model contribution is in the formulation of its objective function as it includes a gross profit generated from integrated systems like the one for the optimization of the ship voyage and the other one for the optimization of the ship allocation. The former creates input voyage parameters needed by the latter, and then the latter generates the yearly gross profit based on the trade area allocated to new ships in fair competition with already existing ones. The contribution is also made by the calculation of three net present values based on three levels of the stochastic cargo transport demand; one optimistic, one most likely, and one pessimistic.

the-ship-allocation model and then to the new-shipappraisal model to calculate the three net present values.

The impact of the new policy on any logistics and supply chain system is that it maintains the shortest possible transportation time the transportation system can afford. Findings of this new policy can easily be extended to transportation systems other than cargo ships; namely cargo airplanes, trucks, and trains.

In Section 5, it was shown that the optimal gross profit generated for each ship in each trade area could be used to allocate ships' voyages to world cargo trade areas within a long-term planning period. One useful application of this allocation is to consider the frequency of calls allocated in each trade area as representing demand of services provided in this area and use this demand to assess the competitiveness of utilities in cargo trade areas. Ports are taken as an example for such utilities, and the frequencies of call of a fleet of tankers are used to represent the demand for services rendered by these ports. The analysis given by El Noshokaty (2017a) demonstrates the case where an optimal trade area improvement is advised by the optimization-of-ship-voyage model and the optimizationof ship-allocation model so that all calling frequencies in this area are serviced and ship layups are avoided while maintaining maximum revenue of area ports. Sensitivity and what-if analysis described in Section 4 is the tool to reach this optimal trade area improvement. Findings of this analysis can easily be extended to other ship types, Another useful application of the optimizationof-the-ship-allocation model is that it calculates the gross profit of the new ship each year of its lifetime when it is added to old fleet units in the allocation plan. The new-ship-appraisal model, as described in Section 6, can then calculate three appraisal values, corresponding to three levels of stochastic cargo transport demand: an upper limit, deterministic equivalence, and lower limit. El Noshokaty (2017a) can calculate the three net present values for an oil tanker to be purchased for tramp shipping service and demonstrates how the deterministic-equivalent value represents the most likely value in a range of values bounded by lower and upper limits.

Future work is suggested to go further in adding more shipping elements and rules, so that tramp shipping models become more realistic. Elements such as flexible cargo sizes, splitting of loads, and different ship speed, although they affect profitability if formulated within the models, they can be handled instead by sensitivity and what-if analysis, giving other elements the chance to be formulated. Stochastic and profit-per-day-objective models need to have more attention. Cargo transport demand needs more study on the construction of probability distribution of the transport demand for main types of cargo. OR-Based Decision Support Systems are used to integrate OR models into database management systems. It is highly recommended to build such systems for shipping, so that OR methodologies become transparent to ship owners while being supportive at the same time. Moreover, these systems have to interact with the ship owner in friendlier sensitivity and what-if analysis sessions. Because the speed of computer hardware represents the principle limitation of the algorithms adopted in nowadays' research papers, faster computer hardware, and communication equipment must be used to enable ship owners to take their decisions in the right time. Ship owners, operators of utilities, and researchers are encouraged to meet somewhere to discuss problems of mutual concern. It is highly recommended that workshops are to be considered as the places where all should meet to discuss case studies. It is the role of international conferences to arrange such workshops in different places worldwide. The future work on tramp shipping should result in an impact on the logistic system in which transportation by ship is part of. Finally, the stochastic gross profit-per-day objective may be used in other time-sensitive production cycles. Examples are crop charts in agriculture, customized production line in the industry, product maintenance schedule in services, project plan in construction, and logistics network in trade. It may be used as well in fixed-time production cycles, before time being fixed, to determine the optimal amounts of factors of production employed in a multiple-products multiple-systems investment plan. Examples are crop harvesting in agriculture, car manufacturing and assembly lines in the industry, port cargo handling in services, road paving in construction, and market control measurements in trade.

other port services and other utilities; namely canals and straits. [1]

Figure 1:

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for validity, and with no facilities for non-OR users to

these papers. The state-of-the-art Block-Angular Linear

Ratio programming methodology (El Noshokaty, 2014) is used to solve the problem. El Noshokaty (1988) has first developed a shipping model with gross profit per day objective for only one ship using Fractional programming methodology.

?? ð ??"ð ??" ?? be voyage close day of ship ?? ? ??, ?? 0 ?? be

?? 3 =??? ? ??(??? ? (1)
??ð ??"ð ??"?j ? ??g ?? ????
?? ?? ???? ?? ? ?? 0 ??)/??
ð ??"ð ??" ??

[Note: Gross profit equals freight plus demurrage (based on reversible or irreversible calculation), minus cooling/heating cost of cargo ?? ? ?? at ?? ? ??, minus handling cost of cargo ?? ? ?? at ?? ? ??, minus dispatch (based on reversible or irreversible calculation), minus port dues of port ?? ? ?? at ?? ? ??ð ??"ð ??", where ???? ? ????, and minus canal/strait dues and fuel consumption of main where ???? ? ???? , } Subject to:]

Figure 2:

? ? (10) ? ?? ? = ? ? ?? ? ? ? ?ð ??" ? ? ?ð ??" , ? ? ? , and ? ? ? , ? ? ? ? ? ? ? ? + ? ? + ? ?? ?

? Event time precedence constraints which control

? arrival times so that arrival day at discharge event ? ð ??"? ? ? 1 ???ð ??" , ? ? ? , ? ? ? ? ? ? ? ? ,

? Time window constraints which restrict the ship

? arrival day at event ?? ? ?? so that it does not violate ? ?? ? = ? ? ?? ? ? ? ? , ? ? ? , ? ? ? , ? ?

?? ? + ? ?? ? ? 1 , ? , ? ? ? , and ? ? ? , ? ? ? ?? ? (13)

? 1 , ? ? ?ð ??" ? ? ? ? ? ? , ? ? ? ? , ? ? ?, and ? ? ?,

where ? ? ? ? ?? ? ???ð ??" = 1,

(1 ? ?? ???? ??) + ?? ?? where ?? is a big number. So ?? ?? ?? ? ?? ?? ?? ? ???? ?? ???? ?? , ?? ?

?? be the number of days taken to handle cargo ?? ? ?? at ?? ??

[Note: ? Discharge remaining weight constraints which restrict remaining weight on board each ship at end event ?? ? ?? to be at least equal to remaining weight at start event ?? ? ?? of any transport link plus weight of cargo ?? ? ?? at event ?? ? ??, given by: event ?? ? ?? by ship ?? ? ?? plus waiting days at port ?? ? ?? at event ?? ? ??, ?? ???? ?? be the number of days taken to sail the transport link from event ?? ? ??ð ??"ð ??" to event ?? ? ??ð ??"ð ??" by ship ?? ? ?? plus waiting days at sea, where ???? ? ????, ?? be voyage slack days of ship ?? ? ??, if it arrives earlier than ??????, aggregated for all ?? ? ?? and ?? ? ??,]

Figure 3:

? = ? ? ? ? ? ? ? ? ð ??" ? ?? ? ? ? ? ? ?
?? ? ? ?
? ? ? ? ? ?? ? ?? + ? ? = ? ? , ? ? ? ,
? ? ? ? ? ? ? ? ? ? ?? ? ? ? , ? ? ? ,
? ?? ? 0 , VI.

Figure 4:

Cash flow items, other than that related to gross profit,
include loan installments, loan interest, tax, tax relief,
and grants,
???? 0 be the cost of investment of ship ?? ? ??,
???? be the risk-based rate of return on investment for ship

[Note: ?? ? ??, e be the rate of economic inflation. The net present value; ?? ?? ?? , is equal to the discounted net cash flow of ship ?? ? ?? based on ?? ? ?? cargo transport demand index, as shown by:]

Figure 5:

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