A Systematic literature review on maritime transportation optimization using linear programming

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Abstract. Maritime transportation has a decisive position in world trade. Along with the development of science and technology, maritime transportation faced more complex and robust problems in term of their optimization. In this paper, we purpose a Systematic Literature Review (SLR) on Maritime Transportation Optimization (MTO) in three-level decision making that is the strategic planning level, tactical planning level, and operational planning level. We also have identified Linear Programming (LP) as a proper preference to study MTO. This SLR using a structured approach that involves bibliometric and network analytics from the articles published during 1976 – 2019. Some of the key findings in this study as follows, (i) research and citation in MTO using LP is rising and reached its peak in 2018; (ii) three countries with the highest number of articles are the United States, Norway, and China; (iii) shows a great opportunity for future research to combine strategic planning, tactical planning, and operational planning.

1. Introduction
Maritime transportation is an amazing system that continues to work without being seen. It serves almost all types of shipping every day throughout the year to all the world. The terminology of maritime transportation can be classified under different characteristics such as geographical (short sea shipping, coastal waterway, deep-sea shipping, and inland waterway), planning level (strategic, tactical, and operational), operation (liner, tramp and industrial), and cargo (container, bulk, chemical, LNG, general cargo) [1]. Maritime transportation optimization (MTO) using linear programming (LP) has received enormous attention in recent decades, mainly because of the rapid progress in computer technology. Primary research is classified using three different planning level. The strategic planning level mostly about the optimal fleet size and the tactical planning level involves constructing a set of routes which known as ship routing and scheduling. Furthermore, the operational planning level focus on the cargo routing problem. The first paper that can be tracked about MTO is Ronen [2]. It’s evaluated routing and scheduling that made a comparison between the network of road truck and ship. Although each mode of transportation has a difference in service, in terms of networks there are similarities.

Thus, Ronen [3] and Christiansen et al [4, 1] continue their valuable scientific work to produce MTO in term of ship routing and scheduling. More than a decade later, Christiansen et al [5] managed to publish ship routing and scheduling article as a follow-up from [4]. In 1996, Cho and Perakis [6] studied to combine two different planning level (strategic and tactical) using two LP-models. First, an LP model with maximizing a profit to provide the optimal ship routing. The second model is a mixed-integer LP
model that cover optimal routing and fleet capacity. Continuing the work from [6], Fagerholt [7] focused to find an optimal strategic planning level in ship routing problem. His work is tested by making a network system for The Norwegian Coast shipping company.

On the cargo routing problem, Shintani et al [8] combined two types of planning level. She formulated cargo routing problem together with vessel deployment where the problem is described through 2 stages. Agra et al [9] researched on a single product which classified in maritime inventory routing problem (MIRP). This paper discussed the iteration between two types of problems, master problem, and adversarial separation problem. With using a decomposition algorithm, they can make master problem infeasible. This can be another new problem, but with some new strategies such as an iterated local search heuristic, they can reduce the running time and number of iterations. And, Foss et al [10] studied ship routing with a combination of inventory planning in port for bulk tankers. Foss using the mixed-integer programming which adds some valid inequalities, so the model becomes powerful. Later, Mulder and Dekker [11] combined three different planning level approach that is optimal fleet size, ship routing and scheduling, and cargo routing. They focused on the liner shipping and decided to make a model using the aggregation of ports. But when this paper cover so many problems in running the model, they also used a combination approach to solve three different planning level together. In this paper, Mulder and Dekker implemented their model by using trade lane data from Maersk in many ports on the Asia and Europe regions.

The purpose of this paper is to present a systematic literature review (SLR) which refers to the structured, systematic and pointed literature review in MTO using LP. SLR used to avoid bias in the traditional literature review, which comes from broader of the topic and the sources of the literature are not necessarily specified. This structural literature consists of rigorous bibliometric tool and network analysis. A bibliometric tool is an efficacious approach to flaunt bibliographic data such as citation and co-citation for huge numbers of articles in a structured form. With this approach, researchers can analyze relationships internally and analyze a comprehensive network. This analysis also can be performed with a visualization [12]. This review adopted Bibexcel software to analyze MTO using LP because of its powerful competence to carry out bibliometric data easily as needed. Then, we visualize the network analysis using VOSviewer, a modest system and proficient to display images greatly.

Table 1 shown certain articles with a general description as the background of this study. In this study, we used the SCOPUS as a search engine to find relevant and reliable articles which considered a term of MTO using LP. The SCOPUS is well known as very complete and tested as a peer-reviewed literature source in the field of science and technology [13]. We were seeking for relevant articles by 1976-2019. The articles come from the journal, book, distinguish conference, book chapter, and review. At last, 87 articles were selected to review.

This paper is divided into several passages. In part 2 describes the research methodology. While in part 3 explains in-depth related to bibliometric analysis using BibExcel. Part 4 describes network analysis by conducting keyword groupings and author collaboration in the MTO field with the LP approach. In part 5 summarizes the conclusions of this study and the possibility of future research opportunities.

2. Research methodology
SLR is done by using a repetitive cycle, starting with the use of search keywords, searching the articles and finishing the analysis. This SLR produces a grouping of important analyzes relating to the author, institution, producing country, funding source, level of collaboration and determining the direction of publication in the future [14]. We follow Rowley [15] in designed a research methodology by using step by step structural approach. We used five levels methodology that is finding the right keywords, initial search result, evaluation data statistics, bibliometric approach, and network analysis to evaluated articles related to MTO using LP.
| No | Title                                                                 | Authors                | Key issued                                                                 | Key finding                                                                 | Level Decision Making        | Type of Linear Programming (LP) |
|----|------------------------------------------------------------------------|------------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------------|--------------------------------|
| 1  | Integrated scheduling of vessel dispatching and port operations in the closed-loop shipping system for transporting petrochemicals | An et al. [16]         | Presented a combination problem of ship scheduling and operation in port.  | By using the new formula (heuristic algorithm), appear cost savings are in average 10.4%. And if a new model and CPLEX combined, the result in cost savings is 11.3%. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 2  | Liner shipping routing, fleet sizing and speed optimization with application to Asia - Northern Europe-trade | Chaibou et al. [17]    | Focus to combine three problems (ports, speed, and number of the ship) to attain the minimal cost fuel of bunker and fixed costs of the ship. This problem was implemented in liner shipping. | They provided a new model with a modest judgment tool that synchronized among the best line, got the lowest costs and finding the best networks. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 3  | Short-term planning of liquefied natural gas deliveries                | Msakni et al. [18]     | Investigated ship scheduling in LNG with examining cargoes level of importance, a different type of vessel and with steady speed. | This paper giving a huge realistic example in ship scheduling and can be resolved superbly. One of the main discoveries is showing how important it is to control the speed of a ship. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 4  | Optimization of a small-scale LNG supply chain                         | Britani et al. [19]    | Showed problem in a transportation line among producer ports and received ports with several goods transported. | Implemented in the Caribbean area, the model can cover transportation problem satisfying between the producer ports in a remote area and the five received ports. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 5  | Global reverse supply chain design for solid waste recycling under uncertainties and carbon emission constraint | Xu et al. [20]         | Investigated the problem in design the network of waste supply chain (GRSC). This design included the level of uncertainty in the collection of waste, the number of emissions and faced in cost problem. | They used a robust model, the three problems in GRSC are shown with a better result even if complicated interactions GRSC also taken into account. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 6  | Improving maritime inventory routing: application to a Brazilian petroleum case | Diz et al. [21]        | Studied about inventory routing problem where the ship carries crude oil from the production site on land to the port. An important limitation that must also be considered in this model is the ability to maintain the level of availability of existing crude oil. | They used the MILP model, which showed incredible transport cost efficiency by 20% on average. When this model is applied to real case examples, it can also solve problems offloading and supply problem. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 7  | Bulk ship fleet renewal and deployment under uncertainty: A multi-stage stochastic programming approach | Arslan et al. [22]     | This paper provided a model with many phases in stochastic programming for the first time. This model is used in bulk ship fleet for the replacement stage. | They found efficiency in total cost about 4% with using stochastic model compared to the deterministic approach. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 8  | Optimal planning of liquefied natural gas deliveries                   | Al-Haidou et al. [23]  | Studied planning of delivery LNG with included not only the long dates of cargo delivery but also the chosen of ships. | An output showed the greatness of the model in the real case from energy company which has 118 cargoes in 373 days inspected. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| 9  | Approximate dynamic programming for a class of long-horizon maritime inventory routing problems | Papageorgiou et al. [24] | Focused on long term operational planning problem by making approximate dynamic programming (ADP). | Showed that the ADP model is a good solution to generate a big number of ports and vessels combining by other commercial solvers. | √                             | Integer LP, Binary LP, Mixed Integer LP, other |
| No | Title                                                                 | Authors                  | Key issued                                                                 | Key finding                                                                 | Level Decision Making | Type of Linear Programming (LP) |
|----|----------------------------------------------------------------------|--------------------------|----------------------------------------------------------------------------|-------------------------------------------------------------------------------|----------------------|-------------------------------|
| 10 | A maritime container repositioning yield-based optimization model with uncertain upsurge demand | Wong et al. [25]         | Investigated a new type of a yield-based container that counting the container repositioning which considers the surplus area and deficit area. | This model showed the optimal in a yield-based container and gain more profit while considering some condition. | Strategic          | Tactic | Operational | Integer | Binary | Mixed | Other |
| 11 | Routing and fleet deployment in liner shipping with spot voyages    | Branchini et al. [26]    | Developed a model that reflect two different voyages, contractual and spot, to maximize the profit by including route selection and ship scheduling. | Showed a better profit by 12% for a group of ships with comparing problems between the spot voyages and without spot voyages. |                     |                   |                 |         |        |       |       |
| 12 | Alternative mixed-integer linear programming models of a maritime inventory routing problem | Jiang et al. [27]       | Investigated two models on the operational level that is the continuous-time and discrete-time. The first models based on setting time in a single shipyard while others consider a single good in a fixed-charge network flow. | Showed continuous-time models had better computational result from the discrete-time model. |                     |                   |                 |         |        |       |       |
| 13 | Segment-based alteration for container liner shipping network design | Wang et al. [28]        | Investigated the change of optimal cargo in the liner shipping network from head port to tail port with one ship can visit one port more than once. | The model solved the problem efficiently by reducing the total cost and implement in Asia-Europe-Asia liner shipping network. |                     |                   |                 |         |        |       |       |
| 14 | A tailored branch-and-price approach for a joint tramp ship routing and bunkering problem | Meng et al. [29]        | The paper deals with the question of how Tramp Shipping route maximize their profit while cargo and bunker need to purchase in every port with many cargo and ports have different bunker prices? | By using this model, the problem had solved and outpaced the general model. This model made an interesting finding by combining better future cargo demand prediction. |                     |                   |                 |         |        |       |       |
| 15 | Solving the 3-D yard allocation problem for break bulk cargo via variable neighborhood search branching | Bruglieri et al. [30]   | Investigated the problem in the cargo yard for breakbulk. This case study presented in Port Yard of Vitoria, Brazil using MILP. | A design a showed promising and better result than CPLEX solver and less time. |                     |                   |                 |         |        |       |       |
| 16 | Alternative approaches to the crude oil tanker routing and scheduling problem with split pickup and split delivery | Hennig et al. [31]      | This paper focused on an oil tanker in tactical planning level (routing and scheduling) by comparing the path flow model in term of applicability. | From the time optimization, root node and gap perspective, the discrete cargo model showed a better result than continuous approach. But from solution perspective has less quality. |                     |                   |                 |         |        |       |       |
| 17 | MIRPLib - A library of maritime inventory routing problem instances: Survey, core model, and benchmark results | Papageorgiou et al. [32] | Presented MIRPs in ocean line for a single product in extensive explanation | Developed a maritime inventory routing library called MIRPLib to help planner, researcher, and student to gain proper material. | |                   |                 |         |        |       |       |       |
| 18 | Two-stage decomposition algorithms for single product maritime inventory routing | Papageorgiou et al. [33] | Studied two different algorithms for a single product in MIRPs that had substructure. | This model showed their superiority to break the problem by using a commercial solver. | |                   |                 |         |        |       |       |       |
| 19 | Network design approach for hub ports-shipping companies competition and cooperation | Augeri et al. [34]      | Designed a network using the game-theoretic model with three propose conditional. The network design included hub port and shipping companies to stimulate competition between them. | First and second scenario yield an optimal solution for the theoretic network, albeit with the contrary optimum condition of the key parameter (THC). The third scenarios did not yield an optimum solution. | |                   |                 |         |        |       |       |       |
2.1. Finding the right keywords

We designed a four-step using the right keywords each step to filtering articles. Maritime transportation is a general term related to sea shipping, but despite very huge maritime characteristics, in this research, we use another terminology to gain another maritime transportation article. Since MTO is related to linear programming and in this case, we exclude non-linear programming, thus we choose these two words as keywords. The first step we add 6 keywords which has the same terminology as maritime transportation. In the second step, we put 5 keywords in term of optimization and the third step we used only one keyword namely linear programming. The last step is used to put out keywords that are out of scope.

Table 2. The Steps of finding the right keywords

| Step | Term                  | Keywords                                                                 | No. of papers |
|------|-----------------------|--------------------------------------------------------------------------|---------------|
| 1    | Maritime Transportation| "Maritime Transportation" OR "Seaborne Transportation" OR "Water-borne Transportation" OR "Coastal Transportation" OR "Short Sea Shipping" OR "Inland Waterways" AND | 6257          |
| 2    | Optimization          | "Optimization" OR "Optimisation" OR "Optimize" OR "Optimising" OR "Improvement" AND | 1341          |
| 3    | Linear Programming    | "Linear Programming" AND NOT                                              | 93            |
| 4    | Out of scope          | "Non-linear Programming" OR "Non Linear Programming"                      | 87            |

2.2. Initial search results

From the first step of finding the right keywords about 6257 papers found in the SCOPUS database. For the second step, the papers reduce until 1341 papers and with the third step, about 93 papers selected. Finally, 87 papers were selected using the fourth level (Table 2). Those 87 papers using RIS export menu in SCOPUS were stored. This stored file contained citation information, bibliographical information, abstract and keywords, funding detail and other information includes the reference. Later, we used it as a primary source to analyzed by Bibexcel.
2.3. Evaluation data statistics

In the first part of the evaluation data statistics, showed extraction for 87 papers from 55 publishers in publication trend. Figure 1 gives an illustration of the publication trend to the selected papers in the year 1976-2019. Based on the illustration, publication trend can be grouped into two periods. The first period called stagnant period (1976–2009) and the second was a rising period (2009-2019). From the first period, the limited paper was published and only the top 2 papers in one year. In the rising period, researchers started to giving attention to this topic with a total of 76 papers were published and reach its peak in 2018 with 14 papers.

Table 3 shows the top journals that come from extracted papers. This top 10 journal representing 48% of all paper publish. European Journal of Operational Research and Transportation Research Part E Logistics and Transportation Review were the 2 highest journals with 8 and 7 papers. Area study of the journals was wide, not only transportation, logistics, and maritime area but also from operational research, computers, and algorithms discipline. Most of top 10 journals published by Elsevier, only 3 of them published by Taylor & Francis (Journal Maritime Policy and Management), Multidisciplinary Digital Publishing Institute (journal Algorithms), and Institute for Operations Research and the Management Sciences (Journal Transportation Science). There are also discovered 1 article form undefined journal. European Journal of Operational Research which has the first rank is found as the highest cited journal among others. Six journals of the top 10 come from transportation and maritime discipline and the rest comes from the computer and operational research.

Table 3. The top 10 journals in the field of MTO using LP

| Journal                                      | Publication year | Total |
|----------------------------------------------|------------------|-------|
| European Journal of Operational Research    | 1                | 8     |
| Transportation Research Part E Logistics and Transportation Review | 1 2 1 1 1 1 1 | 7     |
| Transportation Research Part C Emerging Technologies | 1 1 1 2 | 5     |
| Computers and Chemical Engineering           | 2 1             | 4     |
| Transportation Research Part B Methodological | 2 2          | 4     |
| Transportation Science                      | 1 1 1 1        | 4     |
| Computers and Operations Research            | 1 1 1           | 3     |
| Transportation Research Record               | 2 1            | 3     |
| Maritime Policy and Management Algorithms    | 2 2            | 4     |
| Total                                        | 7 2 3 2 8 4 5 5 | 41    |

2.4. Data analysis

In this section, there are two steps to be taken, bibliometric approach and network analysis. The first approach represents the author influence, affiliation from both the country and institution, keywords, and subject area. All data that shown in this paper is coming from extracting 87 selected articles. To ease the analysis, the process of a bibliometric approach is done using the Bibexcel program, which appropriates to other computer programs [35]. The second analysis covers citation, co-citation, co-author, and co-word analysis. We use VOSviewer to elaborate network analysis because of its convenience and simplicity to working with large data sets.
3. Bibliometric approach

We use Bibexcel to analyze bibliometric approach. The data source used as input into Bibexcel is in RIS format from SCOPUS database containing the bibliographic information and citation information of the articles such as subject area, author, affiliation, publication year, type of document, publisher, keyword, territory/country, funding sponsor, reference, and type of publication. The following part discusses the author influence, affiliation, keywords and subject area as an output from Bibexcel.

3.1. Author influence

Table 4 informs the top 10 contributing authors in the field of MOT using LP. The calculations performed here are based on the number of publications carried out by the author not only as the first author. Christiansen, M. and Fagerholt, K. from Norwegian University of Science and Technology are the top contributing authors. As can be seen, each of them being author and co-author in vice versa. These two researchers had known as a pioneer who contributes a lot in the development of MTO. There are also Exxon Mobil Corporation and the National University of Singapore who sending 2 authors in the top 10 contributing authors. The Georgia Institute of Technology is known as one of the center research for MTO.

| No | Author             | Institution                                | No. of papers |
|----|--------------------|--------------------------------------------|---------------|
| 1  | Christiansen, M.   | Norwegian University of Science and Technology | 8             |
| 2  | Fagerholt, K.      | Norwegian University of Science and Technology | 6             |
| 3  | Hvattum, L.M.      | Molde University College                   | 6             |
| 4  | Papageorgiou, D.J. | Exxon Mobil Corporation                   | 5             |
| 5  | Wang, S.           | Hong Kong Polytechnic University           | 5             |
| 6  | Meng, Q.           | National University of Singapore           | 4             |
| 7  | Nemhauser, G.L.    | Georgia Institute of Technology            | 4             |
| 8  | Agra, A.           | Universidade de Aveiro                     | 3             |
| 9  | Cheon, M.S.        | Exxon Mobil Corporation                   | 3             |
| 10 | Karimi, I.A.       | National University of Singapore           | 3             |

3.2. Affiliation analysis

The affiliation analysis is presented in Table 5 dan Table 6. We analyzed that the Norwegian University of Science and Technology is the top-most contributing institution with publishing 13 papers and followed by National University of Singapore (10 articles) and the Georgia Institute of Technology comes with 6 papers. Even with one or two researchers, the institution can emerge as top rank. The United States comes as the first country with 31% (28 papers) followed by Norway (13 papers), China (11 papers), and Singapore (10 papers) as exhibited in table 6. Thus, the contribution based on countries is equal between the western and eastern with the emergence of two Asian countries.

| Organization                                | No. of papers |
|---------------------------------------------|---------------|
| Norwegian University of Science and Technology | 13            |
| National University of Singapore            | 10            |
| Georgia Institute of Technology             | 6             |
| Exxon Mobil Corporation                     | 5             |
| Hong Kong Polytechnic University            | 3             |
| Molde University College                     | 3             |
| Aveiro University Campus                    | 3             |
| University of Belgrade                       | 3             |
| Qatar University                             | 3             |
| SINTEF Ocean                                 | 3             |

| Country        | No. of papers | Percentage of contribution (%) |
|----------------|---------------|--------------------------------|
| United States  | 28            | 32.18%                         |
| Norway         | 13            | 14.94%                         |
| China          | 11            | 12.64%                         |
| Singapore      | 10            | 11.49%                         |
| South Korea    | 7             | 8.05%                          |
| Australia      | 6             | 6.90%                          |
| France         | 6             | 6.90%                          |
| Hong Kong      | 6             | 6.90%                          |
| Portugal       | 5             | 5.75%                          |
| Brazil         | 4             | 4.60%                          |
3.3. **Keywords analysis**

The purpose of this analysis is to evaluate words or phrases that come from titles, keywords, and abstracts. Table 7 is about top 10 most subject area related to MTO using LP. Whereas transportation and logistics (in this case maritime transportation) is a very broad but the engineering still gain the highest ranking (25.27%) followed by social sciences and computer sciences with 16.13% among the top 10 most subject area. Table 8 given top keywords comes from 87 papers. Through the extracted papers, 744 keywords appear with sequences ranging from the most widely used words are maritime transportation, waterway transportation, optimization, and integer programming. Linear programming and mixed-integer linear programming are considered as the most popular keywords too since they show in two different terms.

In this section, the “optimal fleet size” term that points to the strategic planning level does not appear, but the term of the “ship routing and scheduling” that represent tactical planning levels appear and rank in the top 5. While for the terminology of “cargo routing problem”, which is part of operational planning, only appears in the order of 17 most. Using co-occurrence analysis, we can give a more comprehensive illustration. Co-occurrence analysis is performed using the VOSviewer program at 87 articles from index keywords can be seen in Figure 2. Most of the words in the image are compatible with table 8. This shows that the word chosen when searching for articles is correct.

| Subject Area                      | No. of papers | Percentage of contribution (%) |
|----------------------------------|---------------|--------------------------------|
| Engineering                      | 47            | 25.27%                         |
| Social Sciences                  | 30            | 16.13%                         |
| Computer Science                 | 30            | 16.13%                         |
| Decision Sciences                | 24            | 12.90%                         |
| Mathematics                      | 19            | 10.22%                         |
| Business, Management and Accounting | 19          | 10.22%                         |
| Environmental Science            | 7             | 3.76%                          |
| Chemical Engineering             | 5             | 2.69%                          |
| Economics, Econometrics and Finance | 3            | 1.61%                          |
| Energy                           | 2             | 1.08%                          |

| Keyword                          | Frequency of use |
|----------------------------------|------------------|
| Maritime Transportation           | 55               |
| Waterway Transportation           | 43               |
| Optimization                     | 27               |
| Integer Programming              | 22               |
| Ships                            | 19               |
| Scheduling                       | 17               |
| Linear Programming               | 15               |
| Shipping                         | 15               |
| Fleet Operations                 | 14               |
| Mixed Integer Linear Programming | 12               |
| Costs                            | 11               |
| Inland Waterways                 | 11               |

4. **Network analysis**

Network analysis conducting to investigate the citation analysis, co-citation, and co-word analysis from 87 papers. VOSviewer was chosen for this analysis. By using RIS format data from SCOPUS database, VOSviewer can design special graphics to evaluate.

4.1. **Citation analysis**

This analysis would show the degree of relationship between papers. Table 9 shows the top 10 most cited papers which contain global and local citation. The global citation refers to all SCOPUS citation to the paper, while the local citation is the number of citation comes only from selected 87 papers. Paper form Christiansen has the biggest global citation and local citation. its show that paper in the area of MTO using LP was used in the broad subject. Figure 3 gives a visualization for citation analyzing by the document.

4.2. **Co-citation analysis**

Depictions made on co-citation depend firmly on graph theory in data structures [36]. In this analysis, co-citation will be considered to appear if it appears together on the reference of other paper [37]. Or with another example, paper A is a co-citation paper B because paper B places paper A in the list of references. Therefore, the paper which is often referred to by other papers will tend to enter the same
subject [38]. Figure 4 shown analysis co-citation using VOSviewer that each author at least has 20 minimum citation. Christiansen and Fagerholt presented as the most co-citation among others.

**Figure 2.** Co-occurrence analysis using VOS viewer for index keyword

**Figure 3.** Visualization for citation analysing by document

### 4.3. **Co-author analysis**
From the 87 papers extracted, 160 authors were found. We analyzed that 39 authors from the selected papers wrote at least two papers. Therefore in Figure 5, there is a relationship between the 3 main authors Christiansen, Fagerholt, and Hvattum. In the picture, there also are several different colors that characterize various cluster between one and the other.

| Title of paper                                                                 | Author                                      | Global citation | Local citation |
|--------------------------------------------------------------------------------|---------------------------------------------|-----------------|----------------|
| Ship routing and scheduling in the new millennium                              | Christiansen M et al, 2013 [5]              | 262             | 28             |
| Industrial aspects and literature survey: Fleet composition and routing         | Hoff A. et al, 2010 [39]                   | 174             | 6              |
| Inventory constrained maritime routing and scheduling for multi-commodity liquid bulk, Part I: Applications and model | Al-Khayyal F. et al, 2007 [40]             | 100             | 0              |
| A branch-and-price method for a liquefied natural gas inventory routing problem | Gronhaug R. et al, 2010 [41]               | 81              | 18             |
| The robust vehicle routing problem with time windows                           | Agra A. et al, 2013 [42]                   | 72              | 14             |
| Improving the logistics of multi-compartment chemical tankers                  | Jel Lund A.S. et al, 2004 [43]             | 65              | 15             |
| A mixed-integer linear programming model for bulk grain blending and shipping  | Bilgen B. et al, 2007 [44]                 | 61              | 3              |
| A survey on maritime fleet size and mix problems                               | Pantuso G. et al, 2014 [45]                | 51              | 11             |
| MIRPLib - A library of maritime inventory routing problem instances: Survey, core model, and benchmark results | Papageorgiou D.J. et al, 2014 [32]         | 44              | 7              |
| Network design approach for hub ports-shipping companies, competition and cooperation | Asgari N. et al, 2013 [34]                 | 42              | 4              |

### 4.4. **Co-word analysis**
This analysis takes into account the use of the same keyword from each paper in a selected set of papers [46]. Co-word analysis shows the relationship between groups of words in a cluster, so we can ascertain whether the groups of words in our research have been used by others or not. In this analysis, we used 5 as a minimum number of occurrences of term and produce 6 clusters (figure 6). One of the important
findings in this analysis is the absence of three terminologies from optimal fleet size, ship routing and scheduling, and cargo routing problems in one cluster. We only found the combination between ship routing and maritime inventory routing problem in cluster 2.

Figure 4. Visualization for co-citation analysis

Figure 5. Visualization for co-author analysis

Figure 6. Visualization for co-word analytic

5. Conclusion and potential future research
Using a structured literature review, this paper presented a broad maritime transportation optimization using linear programming. Even many publications have been collected, only a few numbers discuss MTO and LP together. From the early growth phase in 2010-2016, the highest number of papers published related to this subject was found in 2018. In point of view from subject area related to MTO using LP shown that engineering got the highest ranking followed by social sciences and computer sciences. We encourage future research from another subject area and collaborate among subject area, so research can be more comprehensive.
Publisher journal was dominated by Elsevier and the transportation maritime discipline rule more than others even though journal from operational research found as the highest cited journal. From the geographical perspective, the United States emerged as the leading country followed by Norway, China, and Singapore. This condition illustrates that Asia gives considerable attention to the subject area. This was also reinforced by the emergence of the National University of Singapore as the second-largest producer of articles after the Norwegian University of Science and Technology.

From the results of the co-author analysis, it can be seen that the collaboration between several institutions both education and the industry are weak. Researchers prefer to conduct research together with researchers from fellow institutions compared to other institutions, even with industry. This condition shows the great opportunity for cooperation between institutions, given the expertise possessed by researchers is very specific while the scope of MTO and LP is very broad.

In keywords analytic we have found that the term of “optimal fleet size” does not appear, but the term of the “ship routing and scheduling” appear at least 17 times, and for the terminology of “cargo routing problem”, only appears 7 times in articles. In line with that, the co-word analysis found no combination of that three terms in one cluster. It shows a great opportunity for future research to combine that three-planning level in MTO using LP.

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