Empty container reposition using max-min review system: Simulation approach

A Budipriyanto¹, M D Novianti² and T Susanto³

¹, ², ³Industrial Engineering Department, Bakrie University, Jakarta, Indonesia

E-mail: ¹adi.budipriyanto@bakrie.ac.id

Abstract. Global economic conditions and differences in the ability and economic competitiveness of each country cause an imbalance between exports and imports. Shipping of goods is carried out mostly by sea transportation through the use of containers and involves the port as the exit and entry of goods. An imbalance in export-import causes the number of containers in some ports to have a surplus, while others have a deficit. To maintain container availability, shippinglines must adjust the balance by repositioning from a surplus port to a deficit port. Shippinglines must determine the inventory to meet the needs at the port and the number of containers that can be repositioned to the other ports that need it. If the inventory at the port reaches a minimum level, then the order must be immediately carried out, on the contrary, it will be repositioned to another port that needs it. By adopting the concept of a review system (U, D), when the inventory is less than U, an order of Q is immediately placed. But if the inventory is greater or equal to D, repositioning is carried out. Repositioning is done by I-D. In this study, the maximum inventory value is determined based on the value of the inventory service level of 95%. From the simulation results it was concluded that the min-max review system policy with a service level of 95% could reduce inventory by 35.64% and reduce shortage by 8.82%.

1. Introduction

Global economic conditions and differences in the ability and economic competitiveness of each country cause an imbalance between exports and imports [1], [2]. Currently shipments of goods between countries are mostly carried out using sea transportation and shipped using containers [1], [3]–[6]. Based on UNCTAD data in 2011, containers sent from Asia to North America amounted to 12.4 million TEUs, while from North America to Asia only 6.6 million TEUs. In 2012 containers shipped from Asia to North America increased to 13.3 million TEUs, while containers shipped from North America to Asia were only 6.9 million TEUs. [7], [8]. If the port is considered as the origin and destination point, the imbalance of export-import causes a port to become a surplus, while the other port has a deficit.

Shippinglines fill containers from inventory in the form of empty containers owned by shippinglines at the port. The empty container came from a laden container that was sent from another port in the previous period and has been returned to shippinglines in the form of an empty container. The laden container needs time before returning to shippinglines. The location of the return of the container is usually determined by shippinglines, at the depot or at the port. If an empty container is not available shippinglines will rent or request it to be sent from another port. And vice versa, if the inventory at a port is greater than the demand, then the excess empty containers will be sent to the other ports that need them. Shipping empty containers to other ports is known as repositioning. Repositioning the container from the origin port to the destination port requires a lot of time and money.

The cost of repositioning is almost the same as the cost of sending a laden container [2], [9]. The cost of repositioning is high [10]. The cost of repositioning is quite high, consisting of storage costs and transportation costs, and other costs that are not different from the shipping costs of laden containers. [2], [9], [11]. Repositioning an empty container requires the same slot as the laden container, so that it will reduce the capacity to carry the laden container. All repositioning costs are borne by shippinglines. [12]. Therefore to meet the demand for containers, shipping lines must determine the right strategy in implementing the repositioning of empty containers and determining the appropriate inventory.
2. Literature Review

Empty container reposition is a crucial problem for shipping lines [13]. According to [2], 20% of the containers sent were empty containers [2]. Empty container repositioning costs almost the same as sending a laden container but it does not provide added value [14], [15]. The ability to efficiently reposition empty containers can create competitive advantages for shipping lines [2]. The right repositioning strategy can increase service levels and increase productivity in container management [16].

Research on repositioning empty containers by considering laden containers simultaneously was developed by [17]. They formulate it as a two-stage problem. Researcher [18] developed a mixed fuzzy decision making model. They solve this problem with two stages, first using fuzzy backorder quantity inventory decision making, the second stage using optimizing mathematical programming network.

Some researchers develop a repositioning model by considering transportation topology. The single threshold policy model using a hub-and-spoke system was developed by [19], while [20] developed a two-threshold policy for a single port, then expanded to a two-threshold policy for a multi-port system [20]. The threshold system policy model was expanded to become a hub-and-spoke transport system through a dynamic approach [2].

The empty container repositioning with pricing strategy was developed by [21]–[23]. According to [23], pricing strategy can be applied if demand reaches a certain threshold, whereas [21], [22] uses the assumption of the effect of pricing on demand.

Empty container reposition multi commodity, developed by [24]. The repositioned of empty container consists of good containers and damaged containers, so they need to be repaired before being reused by the next customer. This study considers the probability of a damaged container and the time needed to repair it.

The issue of green supply chain in empty containers was initiated by [25], [26]. To support the implementation of the green supply chain, repositioning can be done with collaboration between shipping lines. For collaboration to be effective, it must consider empty container inventory at each port. Repositioning by means of collaboration between shipping lines was developed by [27] by determining the perceived values of empty containers at each port. This model is solved using a two-stage optimization method. A study of the effect of repositioning on CO2 emissions was carried out by [28]. The study results show that an efficient empty container reposition can reduce CO2 emissions significantly.

The combination of cargo routing model with ECR multi services routes, multiple deployed vessels and multiple regular voyages was developed by [29]. The model was solved using two approaches. The first uses the shortest-path based integer programming method, the second uses the two-stage heuristic-rules based integer programming method. A study conducted by [30] was carried out to investigate intermodal repositioning with the aim of minimizing the distribution costs of empty containers. In this model two conditions are considered, first the demand for empty containers is fulfilled from inventory at the port, the second the demands are fulfilled from repositioning.

Returning empty containers can be done directly to the port or returned to the depot. Determining the exact location of returns and the number of depots can minimize costs and reduce the distance of container moving. Research in this area seeks to determine the location of empty container storage, minimize total costs and reduce the distance of container movement. Some models develop flexible depot [31], multi depot [16], and reposition with policy review [20], while [32] develop street-turn models. The model developed by [32] was criticized by [31] because it was difficult to apply. The repositioning of empty containers by considering the route, capacity and frequency of services developed by [33], [34]. They built two models in hinterland transportation, in the first model the ship was allowed to transport containers from different shipping lines, while the second model only transported containers belonging to the shipping lines themselves.

The repositioning of the multi-service route, multi-deployed vessel, and multi-voyage models was developed by [29], [35]. The model is divided into three groups, direct shipping, direct hub and spoke with one transshipment, and direct hub and spoke with two transshipment. The model was completed
using two methods, namely the two-stage shortest-path base integer programming methods, and the two-stage heuristic-rules base integer programming methods. To determine the route and number of repositioned containers, researcher [29] uses the feedback control policy method. Researchers [13] developed a model by distinguishing ship sizes, while [14] developed a combination of hub-and-spoke and multi-port-calling models. According to [36] the location of the shipper is not always close to the port, therefore to meet the demand one must consider the location of the nearest depot [36].

Empty container repositioning model developed by [2] is different from other models. In this model, the ship functions as an inventory warehouse. Empty container is loaded without specifying the destination port and container is unloaded at the port that needs it. They concluded that flexible destination ports provide better results, but the model can only be applied to medium size vessels, for small and large size vessels, the application of flexible destination port is not significant.

The empty container repositioning uses the inventory review policy approach developed by [20], [37]. Review policy (s,S) developed by [16], while [37] developed an inventory review policy (U, D). Both models use the zero lead time assumption for container leasing.

Repositioning by considering uncertainty was developed by [38]. They use uncertainty parameters, namely demand, supply, residual ship space capacity, and residual ship weight capacity. The sample average approximation method is used to solve small-scale stochastic problems and for large-scale use progressive hedging based algorithms. A model to determine the location of empty container depots by considering inventory uncertainty, supply uncertainty, and demand uncertainty was developed by [10]. The solution uses a two-stage stochastic modeling approach. Researchers [39] developed a multi-scenario scenario model for demand uncertainty and supply uncertainty. They developed a hub and feeder model where containers can reach all ports. A cut-and-runs policy is applied to the loading-unloading process.

Other researchers have developed a DSS model for repositioning empty containers where demand and supply are calculated under two conditions, namely deterministic and dynamic conditions [1]. Whereas [9] developed a repositioning model for refrigerator containers.

Technological advances have succeeded in creating containers that can be folded so that repositioning does not require a large place. Some studies related to foldable include [40]–[43]. They developed a mathematical model to minimize the cost of repositioning both foldable and unfoldable containers. Several scenarios were developed and numerical experiments were made to compare the total cost between foldable and unfoldable. Sensitivity analysis is carried out to test changes in purchasing costs and transportation costs for foldable containers. To determine the perception of leasing prices, researcher [44] developed two-stage optimization methods. The first step is to develop a repositioning model by shippinglines. Based on these problems, then used to examine the use of foldable containers. The second stage, based on the solution of the first stage, inverse optimization techniques are used to determine prices at various ports. A mixed-integer non-linear programming model was developed based on the candidate route obtained from the first stage. Then numerical experiments are used to test the effectiveness of the two-stage optimization methods model.

The container planning model with a multi-port multi-period approach to foldable / unfoldable containers was developed by [42]. They build models with the aim of minimizing purchasing costs, repositioning costs and storage costs. Whereas [43], developed a network flow model method for repositioning empty containers by considering foldable containers. They implement two levels of decision, tactical and operational simultaneously. Decisions at the tactical level are needed to determine the route and capacity, while at the operational level it is used to determine the repositioning of containers between terminals.

3. Problem Description

Figure 1 shows the shipping route of the shipping lines from port A to port D and back to port A. The ship takes the route from port A to port D through port B and port C (route: A-B-C-D). From port D, the ship returns to port A goes through port E-F-B and ends at port A (route: D-E-F-B-A).
The ship voyage through the same route so that each port (node) can be function as an initial port (origin) and at the same time as a destination port (destination). For example, if port A is considered as the origin port, then the destination port is port B, C, D, E, and F. Port B is the origin port, while port C, D, E, F, and A will be function as the port of destination, and so on.

![Figure 1. Sailing routes.](image)

Shipping lines only serve shipping containers leased from the shipping lines or containers originating from cooperating forwarders (joining one consortium). Shipping lines must anticipate by making a demand container projection, both to meet the demands at the port itself (i.e., demand containers that will be sent to other ports) and the demand containers needed at other ports (empty containers sent to other ports). For example, container demand at port A is a container demand to meet customers who will send goods using container from port A to ports B, C, D, E, F, and also empty container demands to meet at ports B, C, D, E, F.

Inventory of empty containers in a port or depot comes from 3 sources: beginning inventory, empty containers sent from other ports, empty containers that have returned to port (laden containers that have been empty and returned to shipping lines). Empty containers sent from other ports will become inventory when the containers arrive at the port. Empty container requires delivery time from the original port to the destination, while the laden container that arrives at the destination port must be sent to the consignee, and then the consignee returns the empty container to the depot/port. The time from laden container to empty container cannot be determined. Next, the shipper does stuffing, then sends the laden container to the port.

If the travel time between ports is assumed to be the same, which takes 1 (one) week, then shipping from port A to port B takes 1 week, from port A to port C takes 2 weeks, from port A to port D takes 3 weeks, and so on. Ships from port D returning to A take 4 weeks, because ships from port D to port C must go through ports E, F, B and C. Ships carrying containers from port D to C, or ships from port E to C and D, as well as F to C, D and E must unload the container at port B. Containers unloaded at port B are transferred to the ship from port A to port C.

The uncertainty of the time required from laden container to empty container affects the inventory of containers at a port. Because inventory depends on the time of returning empty containers, inventory is uncertain. The number of import and export containers (inbound and outbound containers) is not always the same (unbalance). At one port the amount of inbound is greater than outbound, and at other ports the number of outbound is greater than inbound. If repositioning is not managed properly, there will be shortages at one port, and there will always be excess at other ports. Therefore, shipping lines must be able to manage and control inventory at each port to avoid shortages and surpluses at a port.

To control the balance of inventory in each port, shipping lines must set the number of empty containers repositioned to each port. Container repositioning does not add value to shipping lines. All repositioning costs are borne by shipping lines, even shipping lines have to sacrifice the capacity available to carry repositioned empty containers. Therefore, repositioning must be arranged in such a way as to minimize costs and maximize demand fulfillment. Unavailability of inventory (shortage) can cause loss of revenue for shipping lines, because customers will switch to shipping lines or other forwarders, where they are competitors.
4. Methodology
The initial stage of this research is literature review related to repositioning empty containers to get a state of the art about empty container repositioning. The next step is to arrange preliminary studies to several shipping lines companies. Preliminary study aims to obtain sufficient initial information related to routing decisions, forecasting (method) decisions, inventory policy, and customer behavior. Based on the existing conditions made a simulation model using ARENA®. The steps for constructing a simulation model are explained as follows:
1. Analysis of problems and information gathering, including identification of input parameters, performance measures, the relationship between parameters and variables. This information is then represented in a logic flow diagram, or presented in an easy and representative way.
2. Data collection, is needed to estimate the input parameters of the model. Analysts are carried out to formulate the distribution of random variables in the model.
3. Model construction, after the problem is clear and the necessary data is collected, the analyst can continue to build the model and apply it as a computer program or as appropriate software (Software Arena).
4. Verification of the model, to ensure the model is made according to specifications. Model verification is done by inspection, comparing models with specifications. If there are differences corrected by modifying.
5. Model validation, carried out to test the suitability of the model with empirical data (measurement of the real system being modeled).
6. Design and conduct simulation / experiment, after the model is valid, proceed with designing a set of experiments to estimate the performance of the model. The analyst can compile a number of scenarios and run a simulation. To achieve statistical reliability of the performance of each scenario, each scenario is replicated (run several times randomly), so that the average yield variability is small (low).
7. Analysis of output, conducting statistical analysis to determine statistical inference in determining whether one alternative scenario has the best performance so it must be chosen as the best scenario.
8. Recommendations, formulate final recommendations based on the results of output analysis.

Schematically, this research methodology can be explained as in Figure 2.

![Research methodology](image-url)
5. Modeling
In this simulation model, repositioning and empty container inventory are considered simultaneously. Supply and demand for empty containers are both uncertain. Shipping routes are fixed.

5.1. Assumption
The assumptions used in this study are as follows:
1. The number of vessels is assumed to be the same and does not change during the simulation time period.
2. Containers are considered only one type (the same size and type and not container refrigerator);
3. The number of containers owned by shipping lines is fixed, has not been added or reduced;
4. The time taken from a laden container to an empty container to the port / depot and ready to be used follows empirical distribution, where 85% of the container returns until the 7th day, and 15% returns after 7 days.
5. Wharfs and loading / unloading equipment at each port, assumed to be able to serve each ship;
6. Container yards at each port are assumed to be able to accommodate all loading / unloading containers and transhipment containers.
7. Ships and container transshipment (at port B) are not specifically considered (scheduling or berth allocation)
8. Ship service time (pillotage service time, mooring, etc.) is ignored.
9. Dwelling time includes the time from the laden container to the empty container.

5.2. Input Parameters
The input parameters used in this study are as follows:
1. Delivery Time, sailing time, ship turnaround time.
   The arrival time of the ship at the beginning of the period is generated using a uniform distribution (UNIFORM (5,7)) days inter-arrival time. For the next period, the time between arrivals at each port depends on the travel time of the ship (voyage) from the origin port to the destination port. Travel time from one port to another port is considered to be the same and follows a uniform distribution (UNIFORM (5,7)) days.
2. Number of container loading and unloading
   The number of containers loading and unloading at each port varies. The minimum, average, and maximum number of container loading and unloading in each port is presented in Table 1.

| Port | Number of Container Loading | Number of Container Unloading |
|------|----------------------------|------------------------------|
| Min  | Ave | Max | Min  | Ave | Max |
| A    | 123 | 977 | 1,770 | 106 | 1,075 | 1,889 |
| B    | 95  | 427 | 1,524 | 74  | 462  | 1,692 |
| C    | 93  | 1,039 | 2,116 | 110 | 975  | 2,065 |
| D    | 194 | 1,874 | 2,853 | 507 | 2,272 | 3,128 |
| E    | 151 | 1,278 | 1,831 | 369 | 1,367 | 2,016 |
| F    | 83  | 783 | 1,695 | 180 | 1,033 | 1,834 |

3. Demand Generator and Demand Fulfillment
Container demand is defined as the number of empty container requirements for a certain period. Empty container needs are met from an inventory of empty containers in the port/depot. As stated earlier, inventory originates from beginning inventory, empty containers sent from other ports, and laden containers that have returned to port in an empty condition.
Container demand can be met if the amount of inventory in one port is greater than demand. If inventory is smaller than demand, shortage will occur. Demands are generated using a uniform distribution based on the data in Table 2.
Table 2. Distribution of Demand

| Port | Demand Distribution       |
|------|---------------------------|
| A    | UNIFORM(123, 977, 1770)   |
| B    | UNIFORM(95, 427, 1524)    |
| C    | UNIFORM(93, 1039, 2116)   |
| D    | UNIFORM(194, 1874, 2853)  |
| E    | UNIFORM(151, 1278, 1831)  |
| F    | UNIFORM(83, 783, 1695)    |

The proportion of loading-unloading to and from the port can be seen in Table 3.

Table 3. The proportion of inbound and outbound in each port.

| From/To | A     | B     | C     | D     | E     | F     |
|---------|-------|-------|-------|-------|-------|-------|
| A       |       | 0.2   | 0.1   | 0.35  | 0.2   | 0.15  |
| B       | 0.1   |       | 0.15  | 0.3   | 0.25  | 0.2   |
| C       | 0.2   | 0.1   |       | 0.35  | 0.15  | 0.2   |
| D       | 0.3   | 0.15  | 0.25  |       | 0.1   | 0.2   |
| E       | 0.2   | 0.35  | 0.1   | 0.1   |       | 0.25  |
| F       | 0.2   | 0.2   | 0.2   | 0.25  | 0.15  |       |

5.3. Verification and Validation

To ensure the model that is built works in accordance with the characteristics of the original system and the results released from the simulation model are within acceptable levels of accuracy, verification and validation of the model must be carried out [45]. Verification assesses the correctness of the model representation by checking coding and test runs, and checking for consistency statistically. Validation assesses how realistic the assumptions on the model are, by comparing the performance of the model (predictions) obtained from test runs with the system under study [46]. Verification consists of three main activities, namely (1) checking simulation logic, (2) simulating test runs and checking printouts and graphs to check that the simulation logic is correct, (3) simple checking of consistency, and more complex checks, between theoretical and statistical simulation results.

Verification of test runs, carried out in several ways, namely verification of input parameters and statistics from the model output, verification using the debugger, verification with animation, verification using statistics or formulation to ensure the model matches to the logic. For Arena simulation, it is necessary to verify more than just models that are built according to the logic or not, but it need to be verified through performance analysis. Verification of animation is used to observe the operating behavior of the model during the running simulation. Several entities are observed to move from entering the system to exiting the system, thus it can be seen whether the entity moves correctly in accordance with the predetermined modeling concept. From the observations of the animation it appears that the entity (ship) moves according to the specified step. The ship came to the arrival station, the ship carried out the process of unloading and loading. From the animation, when the ship is at the berth (the ship is not moving), it is followed by unloading activities for inbound containers. After all outbound containers have finished loading, the ship moves to leave the port. The whole movement is well visualized in animation and in accordance with real conditions. The transfer of laden containers to consignees and from consignees back to the port can be visualized well. Thus the model is verified.

Validation is very important to develop a credible model. The standard approach to model validation is to collect data from the system under study, and compare it with simulation results. In this study validation was carried out on the interarrival time, the number of container loading and unloading, and the amount of inventory. Inventory is adopted from the periodic review system (R, S), where the status of the inventory is reviewed periodically, and when the inventory level reaches point R (reorder point), the order to fulfill a number of S is immediately carried out. In the min-max review system, when the
inventory is greater or equal \( I_{\text{max}} \) (maximum inventory), then repositioning is \( R \) \((I - I_{\text{max}})\). The maximum inventory at each port is determined based on the desired inventory service level, in this study the service level is set at 95%. For example, \( I_{\text{max}} \) at port A is 547, if in a period the amount of inventory at port A is less than or equal to 547, then no repositioning is made, but if it is greater than 547, excess inventory will be repositioned to other ports. The maximum inventory in each port is shown in Table 4. Based on the simulation results, it can meet the specified conditions and provisions, thus the model can be said to be valid.

| Table 4. Maximum inventory at each port. |
|------------------------------------------|
| Port | Inventory Max |
| Port A | 547 |
| Port B | 319 |
| Port C | 811 |
| Port D | 895 |
| Port E | 676 |
| Port F | 327 |

5.4. Run Set Up and Variable Responses
Before the simulation is run, run set up is done first. In this simulation the set up running is done as follows:
- Number of replication : 10 replication
- Replication Length : 8760 hours (24 hour x 365 days)
- Hour per day : 24 hours

Response variables used to assess the performance of the system in this model are the amount of inventory and the amount of demand that cannot be met (shortage).

6. Results and Discussions

6.1. Existing Condition
Table 5 shows the average inventory under existing conditions at each port. At port A the average inventory in replication 1 is 1860 containers, replication 2 is 549 containers, replication 3 is 1161, and so on. The average inventory of replication 1-10 is 1205 containers. At port B the average inventory in replication 1 is 799 containers, replication 2 is 2265 containers, replication 3 is 2547, and so on. The average inventory of replication 1-10 is 2317 containers. At port C the average inventory in replication 1 is 328 containers, replication 2 is 790 containers, replication 3 is 772, and so on.

| Table 5. Average inventory at existing conditions. |
|-----------------------------------------------|
| Replication | A | B | C | D | E | F |
|----------------|---|---|---|---|---|---|
| Replication 1 | 1860 | 799 | 328 | 766 | 937 | 1077 |
| Replication 2 | 549 | 2265 | 790 | 1671 | 579 | 2046 |
| Replication 3 | 1161 | 2547 | 772 | 2260 | 650 | 1461 |
| Replication 4 | 936 | 1158 | 474 | 875 | 679 | 1345 |
| Replication 5 | 1268 | 1487 | 311 | 1105 | 502 | 1252 |
| Replication 6 | 627 | 5037 | 671 | 1169 | 444 | 1006 |
| Replication 7 | 1589 | 4364 | 530 | 1569 | 491 | 839 |
| Replication 8 | 1225 | 3754 | 345 | 754 | 363 | 1886 |
| Replication 9 | 1863 | 902 | 587 | 963 | 759 | 1306 |
| Replication 10 | 975 | 860 | 728 | 3216 | 546 | 707 |
| Average | 1205 | 2317 | 554 | 1435 | 595 | 1293 |
The average inventory of replications 1-10 is 554 containers. At port D the average inventory in replication 1 is 766 containers, replication 2 is 1671 containers, replication 3 is 2260, and so on. The average inventory of replication 1-10 is 1435 containers. At port E, the average inventory in replication 1 is 937 containers, replication 2 is 579 containers, replication 3 is 650, and so on. The average inventory of replication 1-10 is 595 containers. At port F the average inventory in replication 1 is 1077 containers, replication 2 is 2046 containers, replication 3 is 1461, and so on. The average inventory of replication 1-10 is 1293 containers.

Table 6 shows the average shortage in the existing conditions at each port. At port A, the average shortage of replication 1 is 409, replication 2 is 528 containers, replication 3 is 498, and so on. The average shortage of replication 1-10 is 401 containers. At port B, the average shortage of replication 1 is 307 containers, replication 2 is 529, replication 3 is 294 containers, and so on. The average shortage at port B of replication 1-10 is 401 containers. At port C, the average shortage of replication 1 is 644 containers, replication 2 is 843 containers, replication 3 is 705 containers, and so on. The average shortage at port C from replication 1-10 is 703 containers. At port D, the average shortage of replication 1 is 843 containers, replication 2 is 862, replication 3 is 555 containers, and so on. The average shortage at port D of replication 1-10 is 719 containers. At port E, the average shortage of replication 1 is 593 containers, replication 2 is 553 containers, replication 3 is 452 containers, and so on. The average shortage at port E from replication 1-10 is 562 containers. At port F, the average shortage of replication 1 is 502 containers, replication 2 is 514, replication 3 is 553 containers, and so on. The average shortage at port F from replication 1-10 is 488 containers.

| Replication | A | B | C | D | E | F |
|-------------|---|---|---|---|---|---|
| Replication 1 | 509 | 307 | 644 | 843 | 593 | 502 |
| Replication 2 | 528 | 529 | 843 | 862 | 553 | 514 |
| Replication 3 | 498 | 294 | 705 | 555 | 452 | 553 |
| Replication 4 | 541 | 397 | 699 | 833 | 473 | 436 |
| Replication 5 | 424 | 380 | 589 | 580 | 609 | 432 |
| Replication 6 | 558 | 0 | 636 | 604 | 530 | 515 |
| Replication 7 | 437 | 574 | 652 | 710 | 518 | 329 |
| Replication 8 | 564 | 675 | 690 | 863 | 641 | 663 |
| Replication 9 | 441 | 417 | 789 | 811 | 543 | 519 |
| Replication 10 | 449 | 432 | 778 | 526 | 707 | 419 |
| Average | 495 | 401 | 703 | 719 | 562 | 488 |

6.2. Min-Max Review

Table 7 shows the average inventory in the min-max review system for each replication at each port. At port A, the average inventory in replication 1 is 623 containers, replication 2 is 599 containers, replication 3 is 499 containers, and so on. The average inventory of replication 1-10 is 573 containers.

| Replication | A | B | C | D | E | F |
|-------------|---|---|---|---|---|---|
| Replication 1 | 623 | 419 | 495 | 695 | 681 | 577 |
| Replication 2 | 599 | 544 | 578 | 881 | 671 | 475 |
| Replication 3 | 499 | 665 | 648 | 1056 | 555 | 691 |
| Replication 4 | 455 | 562 | 338 | 843 | 588 | 510 |
| Replication 5 | 789 | 554 | 702 | 646 | 575 | 558 |
| Replication 6 | 491 | 614 | 576 | 1087 | 618 | 540 |
| Replication 7 | 499 | 547 | 592 | 843 | 416 | 633 |
| Replication 8 | 603 | 556 | 765 | 948 | 578 | 605 |
| Replication 9 | 681 | 640 | 733 | 972 | 415 | 603 |
| Replication 10 | 495 | 414 | 655 | 1052 | 699 | 593 |
| Average | 573 | 552 | 608 | 902 | 580 | 578 |
At port B the average inventory in replication 1 is 419 containers, replication 2 is 544 containers, replication 3 is 665 containers, and so on. The average inventory of replications 1-10 is 552 containers. At port C the average inventory in replication 1 is 495 containers, replication 2 is 578 containers, replication 3 is 648 containers, and so on. The average inventory of replication 1-10 is 608 containers. At port D the average inventory in replication 1 is 695 containers, replication 2 is 881 containers, replication 3 is 1056, and so on. The average inventory of replication 1-10 is 902 containers. At port E the average inventory in replication 1 is 681 containers, replication 2 is 671 containers, replication 3 is 555 containers, and so on. The average inventory of replications 1-10 is 580 containers. At port F the average inventory in replication 1 is 771 containers, replication 2 is 475 containers, replication 3 is 691, and so on. The average inventory of replication 1-10 is 579 containers.

Table 8 shows the average container shortage for each replication at each port. At port A, the average number of container shortage in replication 1 is 509 containers, replication 2 is 427 containers, replication 3 is 395 containers, and so on. The average number of container shortage of replication 1-10 is 470 containers.

Table 8. Average number of container shortage for min-max review system.

| Replication | A | B | C | D | E | F |
|-------------|---|---|---|---|---|---|
| Replication 1 | 509 | 382 | 578 | 705 | 665 | 427 |
| Replication 2 | 427 | 387 | 609 | 837 | 498 | 355 |
| Replication 3 | 395 | 270 | 818 | 623 | 513 | 434 |
| Replication 4 | 517 | 393 | 549 | 683 | 538 | 435 |
| Replication 5 | 388 | 399 | 608 | 601 | 487 | 444 |
| Replication 6 | 519 | 283 | 504 | 795 | 401 | 376 |
| Replication 7 | 325 | 283 | 654 | 686 | 420 | 419 |
| Replication 8 | 821 | 321 | 602 | 827 | 651 | 346 |
| Replication 9 | 439 | 401 | 679 | 786 | 494 | 386 |
| Replication 10 | 363 | 270 | 603 | 906 | 586 | 393 |
| Average | 470 | 339 | 620 | 745 | 525 | 402 |

At port B, the average shortage of replication 1 is 382 containers, replication 2 is 387, replication 3 is 270 containers, and so on. The average shortage at port B from replication 1-10 is 339 containers. At port C, the average shortage of replication 1 is 578 containers, replication 2 is 609, replication 3 is 818 containers, and so on. The average shortage at port C from replication 1-10 is 620 containers. At port D, the average shortage of replication 1 is 705 containers, replication 2 is 837, replication 3 is 623 containers, and so on. The average shortage at port D of replication 1-10 is 745 containers. At port E, the average shortage of replication 1 is 665 containers, replication 2 is 498, replication 3 is 513 containers, and so on. The average shortage at port E from replication 1-10 is 525 containers. At port F, the average shortage of replication 1 is 427 containers, replication 2 is 355, replication 3 is 434 containers, and so on. The average shortage at port F from replication 1-10 is 402 containers.

6.3. Existing Vs Min-Max Review System

The comparison of inventory and shortage at port A under existing conditions and the min-max review system. In the existing condition, the average inventory is 1205 containers, while in the mi-max review system, the average inventory is 573 containers. The min-max review system can reduced inventory by 632 containers. The average inventory reduction at port A was very significant, with a decrease of 52.45%.

In the existing condition, the average number of container shortage of 495 containers, while in the min-max review system by 470. Min-max review system can reduce the average container shortage by 25 containers or decrease to 470 containers (5.05%). Although the percentage of reduction in shortage is not as large as the decrease in inventory, overall the min-max review system can reduce the average inventory and the average of shortages simultaneously. Comparison of average inventory between existing conditions and min-max review system can be seen in Figure 3, while the comparison of the average shortage between existing conditions and min-max review system can be seen in Figure 4.
Average inventory at port B under existing conditions existing condition is 2317 containers, while the min-max review system is 552 containers. The min-max review system can reduce inventory significantly by reducing the number to 1765 containers. In the existing condition, the average number of shortages is 401 containers and in the min-max review system is 339 containers. The min-max review system can reduce the number of shortages by 62 containers. Although the amount is not too large, the min-max review system can reduce the average amount of inventory and shortage simultaneously.

Figure 5 and Figure 6 respectively show the comparison of average inventory and average shortage at port B under existing conditions and min-max review system.

Figure 7 shows the average inventory and shortage that occurred at port C based on existing conditions and min-max review system. In the existing condition, the average inventory is 554
containers, whereas in the min-max review system the average amount of inventory is 608 containers. In the min-max review system there was an increase in the average amount of inventory by 54 containers or an increase in the average amount of inventory by 9.75% compared to existing conditions. Figure 8 shows the average shortage that occurred at port C in the existing condition was 703 containers, whereas in the min-max review system the average shortage was 620 containers. The min-max review system reduced the number of shortages by 83 containers.

Figure 7. Average inventory at port C.

Figure 8. Number of container shortage at port C.

Figure 9 shows the average inventory and shortage at port D in the existing conditions and in the min-max review system. In the existing condition, the average amount of inventory is 1435 containers, whereas in the min-max review system the average inventory is 902. Min-max review system can significantly reduce the average inventory amount, that is, by 553 containers. In the existing conditions, the average shortage of 719 containers, while in the min-max review system the average shortage increased to reach 745 or an increase of 3.62%.

Figure 9. Average inventory at port D.
Figure 10. Number of container shortage at port D.

Figure 11 shows the average inventory and average port shortage in the existing conditions and min-max review system. In the existing condition, the average inventory is 595 containers, while in the min-max review system the average inventory is 580. The average shortage in the existing condition is 562 containers and 525 containers for the min-max review system. Although not significant, a min-max review system can simultaneously reduce inventory and shortage. Figure 12 show the average number of container shortage in the existing conditions and min-max review system at port E.

Figure 11. Average inventory at port E.

Figure 12. Number of container shortage at port E.

Figure 13 shows the average inventory for existing conditions and the average inventory for min-max review system at port F. In the existing condition, the average inventory is 1293 containers, while the average number of inventory in the min-max review system are 578 containers. Min-max review system can significantly reduce the average inventory amount, which is 715 containers. Figure 14 shows the average number of shortages in the existing condition is 488 containers, whereas in the min-max review system the average number of container shortage is 402. Min-max review system can reduce the average inventory and average shortage significantly and simultaneously.
7. Conclusion
From this research, it can be summarized that in the min-max review system, repositioning is carried out by R (difference between current inventory and max inventory) when the inventory is greater or equal to the maximum inventory with 95% of service level. Overall, the min-max review system policy can reduce inventory surplus by 35.64% and shortage of inventory by 8.82%. The reduction in the amount of inventory that occurs with this system in detail is as follows a much as 52.45% at Port A, 76.17% at Port B, and 37.17% at Port D, where there is an increase at Port C by 9.75%. Another advantage by implementing this system through reducing the number of shortages shortages are as follows namely as much 5.05% at Port A, 15.46% at Port B, 11.81% at Port C, 6.58% at Port E, and 17.62% at Port F, while there is an increasing number of shortage by 3.62% at Port D.

8. Future Research
The next research that can be developed from this research include the following:
1. Research to determine the limits (minimum inventory and maximum inventory) that can be used as a basis for determining ordering and repositioning limits.
2. Research to determine the optimum repositioning value by considering the minimum-maximum inventory at each port.
3. Research to compare the combination of periodic inventory policy and continuous inventory policy, as well as the simultaneous use of policies.

References
[1] Bandeira DL, Becker JL, Borenstein D. A DSS for integrated distribution of empty and full containers. Decis Support Syst. Elsevier BV; 2009 Nov;47(4):383–97. doi.org/10.1016/j.dss.2009.04.003
[2] Song D-P, Dong J-X. Effectiveness of an empty container repositioning policy with flexible
destination ports. Transp Policy. Elsevier BV; 2011 Jan;18(1):92–101. doi.org/10.1016/j.tranpol.2010.06.004

[3] Mason R, Nair R. Supply-side strategic flexibility capabilities in container liner shipping. Xu J, editor. J Logist Manag. Emerald; 2013 May 17;24(1):22–48. doi.org/10.1108/jjlm-05-2013-0053

[4] Feng M, Mangan J, Lalwani C. Comparing port performance: Western European versus Eastern Asian ports. J Phys Distrib & Logist Manag. Emerald; 2012 Jun;8;42(5):490–512. doi.org/10.1016/j/physd.2011.12.002

[5] Asgari N, Farahani RZ, Goh M. Network design approach for hub ports-shipping companies competition and cooperation. Transp Res Part A: Policy and Pract. Elsevier BV; 2013 Feb;48:1–18. doi.org/10.1016/j.tra.2012.10.020

[6] Parola F, Sciomachen A. Intermodal container flows in a port system network. J Prod Econ. Elsevier BV; 2005 Jul;97(1):75–88. doi.org/10.1016/j.ijpe.2004.06.051

[7] UNCTAD, “Review of Maritime Transport 2013,” 2013.

[8] Hsu WK. Improving the service operations of container terminals. Xu J, editor. J Logist Manag. Emerald; 2013 May 17;24(1):101–16. doi.org/10.1108/jjlm-05-2013-0057

[9] Chao S-L, Chen C-C. Applying a time–space network to reposition reefer containers among major Asian ports. Res Transp Bus Manag. Elsevier BV; 2015 Dec;17:65–72. doi.org/10.1016/j.rbm.2015.10.006

[10] Mittal N, Boile M, Baveja A, Theofanis S. Determining optimal inland-empty-container depot locations under stochastic demand. Res Transp Econ. Elsevier BV; 2013 Jun;42(1):50–60. doi.org/10.1016/j.retrec.2012.11.007

[11] Song D-P. Characterizing optimal empty container reposition policy in periodic-review shuttle service systems. J Oper Res Soc. Informa UK Limited; 2007 Jan;58(1):122–33. doi.org/10.1057/palgrave.jors.2602150

[12] Di Francesco M, Crainic TG, Zuddas P. The effect of multi-scenario policies on empty container repositioning. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2009 Sep;45(5):758–70. doi.org/10.1016/j.tre.2009.03.001

[13] Dong J-X, Song D-P. Container fleet sizing and empty repositioning in liner shipping systems. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2009 Nov;45(6):860–77. doi.org/10.1016/j.tre.2009.05.001

[14] Meng Q, Wang S. Liner shipping service network design with empty container repositioning. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2011 Sep;47(5):695–708. doi.org/10.1016/j.tre.2011.02.004

[15] Shintani K, Imai A, Nishimura E, Papadimitriou S. The container shipping network design problem with empty container repositioning. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2007 Jan;43(1):39–59. doi.org/10.1016/j.tre.2005.05.003

[16] Chou C-C, Gou R-H, Tsai C-L, Tsou M-C, Wong C-P, Yu H-L. Application of a mixed fuzzy decision making and optimization programming model to the empty container allocation. Appl Soft Comput. Elsevier BV; 2010 Sep;10(4):1071–9. doi.org/10.1016/j.asoc.2010.05.008

[17] Du Y, Hall R. Fleet Sizing and Empty Equipment Redistribution for Center-Terminal Transportation Networks. Manage Sci. Institute for Operations Research and the Management Sciences (INFORMS); 1997 Feb;43(2):145–57. doi.org/10.1287/mnsc.43.2.145
[20] Li J-A, Liu K, Leung SCH, Lai KK. Empty container management in a port with long-run average criterion. Math Comput Model. Elsevier BV; 2004 Jul;40(1-2):85–100. doi.org/10.1016/j.mcm.2003.12.005

[21] Zhou W-H, Lee C-Y. Pricing and competition in a transportation market with empty equipment repositioning. Transp Res Part B: Method. Elsevier BV; 2009 Jul;43(6):677–91. doi.org/10.1016/j.trb.2008.12.001

[22] Chen R, Dong J-X, Lee C-Y. Pricing and competition in a shipping market with waste shipments and empty container repositioning. Transp Res Part B: Method. Elsevier BV; 2016 Mar;85:32–55. doi.org/10.1016/j.trb.2015.12.012

[23] Xu L, Govindan K, Bu X, Yin Y. Pricing and balancing of the sea–cargo service chain with empty equipment repositioning. Comput Oper Res. Elsevier BV; 2015 Feb;54:286–94. doi.org/10.1016/j.cor.2014.03.001

[24] Hjortnaes T, Wiegmans B, Negenborn RR, Klijnhout R. Minimizing cost of empty container repositioning in port hinterlands, while taking repair operations into account. J Transp Geog. Elsevier BV; 2017 Jan;58:209–19. Available from: http://dx.doi.org/10.1016/j.jtrangeo.2016.12.015

[25] Li L, Wang B, Cook DP. Reprint of “Enhancing green supply chain initiatives via empty container reuse. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2014 Oct;70:190–204. doi.org/10.1016/j.tre.2014.09.007

[26] Zheng J, Sun Z, Gao Z. Empty container exchange among liner carriers. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2010 Sep;46(5):738–54. doi.org/10.1016/j.tre.2010.06.007

[27] Song D-P, Dong J-X. Cargo routing and empty container repositioning in multiple shipping service routes. Transp Res Part B: Method. Elsevier BV; 2012 Dec;46(10):1556–75. doi.org/10.1016/j.trb.2012.08.003

[28] Li L, Wang B, Cook DP. Enhancing green supply chain initiatives via empty container reuse. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2014 Oct;70:190–204. doi.org/10.1016/j.tre.2014.09.007

[29] Song D-P, Dong J-X. Cargo routing and empty container repositioning in multiple shipping service routes. Transp Res Part B: Method. Elsevier BV; 2012 Dec;46(10):1556–75. doi.org/10.1016/j.trb.2012.08.003

[30] WANG B, WANG Z. Research on the Optimization of Intermodal Empty Container Reposition of Land-carriage. J Transp SysT Eng and Inf Technol. Elsevier BV; 2007 Jun;7(3):29–33. doi.org/10.1016/s1570-6672(07)60020-8

[31] Lei TL, Church RL. Locating short-term empty-container storage facilities to support port operations: A user optimal approach. Transp Res Part E: Logist and Transp Rev. Elsevier BV; 2011 Sep;47(5):738–54. doi.org/10.1016/j.tre.2011.01.004

[32] Furió S, Andrés C, Adenso-Díaz B, Lozano S. Optimization of empty container movements using street-turn: Application to Valencia hinterland. Comput Ind Eng. Elsevier BV; 2013 Dec;66(4):909–17. doi.org/10.1016/j.cie.2013.09.003

[33] Braeckers K, Caris A, Janssens GK. Optimal shipping routes and vessel size for intermodal barge transport with empty container repositioning. Comput Ind. Elsevier BV; 2013 Feb;64(2):155–64. doi.org/10.1016/j.compind.2012.06.003

[34] Alfandari L, Davidović T, Furini F, Ljubić I, Maras V, Martin S. Tighter MIP models for Barge Container Ship Routing. Omega. Elsevier BV; 2019 Jan;82:38–54. doi.org/10.1016/j.omega.2017.12.002

[35] Story D-P, Dong J-X. Long-haul liner service route design with ship deployment and empty container repositioning. Transp Res Part B: Method. Elsevier BV; 2013 Sep;55:188–211. doi.org/10.1016/j.trb.2013.06.012

[36] Crainic TG, Gendreau M, Dejax P. Dynamic and Stochastic Models for the Allocation of
Empty Containers. *Oper Res.* Institute for Operations Research and the Management Sciences (INFORMS); 1993 Feb;41(1):102–26. doi.org/10.1287/opre.41.1.102

[37] Young Yun W, Mi Lee Y, Seok Choi Y. Optimal inventory control of empty containers in inland transportation system. *J Prod Econ.* Elsevier BV; 2011 Sep;133(1):451–7. doi.org/10.1016/j.ijpe.2010.06.016

[38] Long Y, Lee LH, Chew EP. The sample average approximation method for empty container repositioning with uncertainties. *J Oper Res.* Elsevier BV; 2012 Oct;222(1):65–75. doi.org/10.1016/j.ejor.2012.04.018

[39] Di Francesco M, Crainic TG, Zuddas P. The effect of multi-scenario policies on empty container repositioning. *Transp Res Part E: Logist and Transp Rev.* Elsevier BV; 2009 Sep;45(5):758–70. doi.org/10.1016/j.tre.2009.03.001

[40] Shintani K, Konings R, Imai A. The impact of foldable containers on container fleet management costs in hinterland transport. *Transp Res Part E: Logist and Transp Rev.* Elsevier BV; 2010 Sep;46(5):750–63. doi.org/10.1016/j.tre.2009.12.008

[41] Moon I, Do Ngoc A-D, Konings R. Foldable and standard containers in empty container repositioning. *Transp Res Part E: Logist and Transp Rev.* Elsevier BV; 2013 Jan;49(1):107–24. doi.org/10.1016/j.tre.2012.07.005

[42] Myung Y-S, Moon I. A network flow model for the optimal allocation of both foldable and standard containers. *Oper Res Lett.* Elsevier BV; 2014 Sep;42(6-7):484–8. doi.org/10.1016/j.orl.2014.08.004

[43] Wang K, Wang S, Zhen L, Qu X. Ship type decision considering empty container repositioning and foldable containers. *Transp Res Part E: Logist and Transp Rev.* Elsevier BV; 2017 Dec;108:97–121. doi.org/10.1016/j.tre.2017.10.003

[44] Zheng J, Sun Z, Zhang F. Measuring the perceived container leasing prices in liner shipping network design with empty container repositioning. *Transp Res Part E: Logist and Transp Rev.* Elsevier BV; 2016 Oct;94:123–40. doi.org/10.1016/j.tre.2016.08.001

[45] N. N. Huynh, C. M. Walton, and R. River, “Methodologies for reducing truck turn time at marine container terminals,” *Cent. Transp. Res. Univ. Texas Austin*, vol. 7, no. 2, pp. 1–144, 2005.

[46] T. Altiok and B. Melamed, *Simulation modeling and analysis with Arena.* 2007.