

Determination of the Storage of the Area Requirements for İzmir Container Port by Implementing the Neural Networks

Mehmet Sinan Yıldırım* and Ümit Gokkus

¹*Manisa Celal Bayar University, Manisa, Turkey*

mehmetsinan.yildirim@cbu.edu.tr

Abstract

Port storage area optimization is resulted from the space allocation requirements of a seaport. Inventory analysis, covered in the scope of operation research topics, is frequently used in the port management such as determining the capacity of the storage areas. In the scope of port planning, the feasible storage area will yield an economic configuration with minimal investment. To achieve this, there must be none or minimum idle container slots in the storage area. In this study, a model based on the inventory analysis considering the minimization of the port expenses was implemented for the İzmir port in Turkey and the optimum future storage area of İzmir port was estimated for the coming years by forecasting the container traffic using Artificial Neural Networks considering the Turkey's economic growth. The study indicated that there is a requirement of a storage area capacity for the coming years. It was found that, the capacity requirement for an optimal storage area management for the seaport was around 10000 containers for 2014, 11000 for 2018 and 12000 for 2023.

Keywords: Container storage, container capacity, yard optimization, port planning, port feasibility, container traffic

1. Introduction

Seaports are essential inter-modal hubs in a transportation network. In the seaport, the requirement of handling the container traffic is a serious challenge for the port authorities considering the limited land allocated as storage area. The determination of the optimum size of storage areas also plays an important role in the port economy. So, container terminals should be planned in accordance with the productivity of handling equipment, the optimum length of quays, and the prevention of idle storage areas [1]. Capacity extension of a seaport is necessary when it reaches its limits. Especially for the seaports surrounded by city limits, the land value usually creates difficulties in extension works. An optimal storage yard operation has been studied by many researchers in literature. A mixed integer-programming model was implemented to determine the optimal number of yard cranes and the location where unloaded containers must be stored[2]. Several metaheuristics were proposed to minimize the space allocated to containers[3]. A heuristic algorithm was proposed for a seaport to solve the location problem of storage areas for export containers[4].A preliminary methodology was proposed to be used in evaluating the capacity analysis of a seaport[5].

In the scope of a capacity extension, determination of the container storage area is a principle problem. To decide a reliable area size, future ship and cargo traffics required to be estimated. The forecasting of the cargo traffic can be performed with the historical cargo traffics or may be related with the arrival and departure ship numbers. In literature there are several efforts to predict the future cargo traffic of a seaport: [6, 7, 8, 9, 10].

Among the forecasting efforts, soft-computing methods such as Artificial Neural Network (ANN) models are widely used in estimation of cargo traffics[7,11].

İzmir commercial seaport, located at the Izmir Bay in the Aegean Sea, is one of the main ports of Turkey with significant container traffic. The port directly located inside the city limits so port operations required to be performed inside a limited area. Beside, İzmir seaport must serve the increasing number of containers through the years with the growth of the Turkish economy. In this study, the capacity of the storage area for the import containers is determined by considering the inventory analysis and cargo traffic forecasting based on the artificial neural networks considering the economic growth of Turkey.

2. Methodology

Inventory theory is a sub-branch of the operation research area considering the design of the inventory systems to minimize the related costs [12]. Particularly for the storage-yard optimization in a seaport, inventory theory offers a mathematical optimization method for determining the feasible storage area capacity. The model is based on the minimization of the total costs: waiting cost due to the queue for the service and cost or loss of income of the seaport operation considering a utilization ratio.

For a container seaport, the variations of the container traffic directly influence the port economy, size of the storage area, quantity of handling equipment, berth capacity and port management. Among these, insufficient storage area resulted from the waiting containers or the container congestion. In a container yard with a specific capacity, during an excessive demand, the number of containers more than the capacity will not be served and the expected income of the port will be lost. Otherwise, existence of the idle container slots will also decreases the profit. Optimization methods provide both the required area for storage by minimization of costs for waiting containers and idle slots for the port management. To optimize the storage yard, the inventory theory can be utilized based on developing a stochastic stock planning model suitable for arrival and service distribution of containers. This model can be developed as the deterministic and stochastic process. The deterministic inventory analysis considers that capacity and unit costs (e.g. cost of invested area per square meters, cost of waiting container per day) are known. On the other hand, stochastic inventory models assign probability distributions representing the unknown data[13]. The optimization problem for the storage area can be summarized as Figure 1[14,15]. Basically, the optimal capacity is determined with the total minimum cost: cost of yard area plus the yard benefit losses.

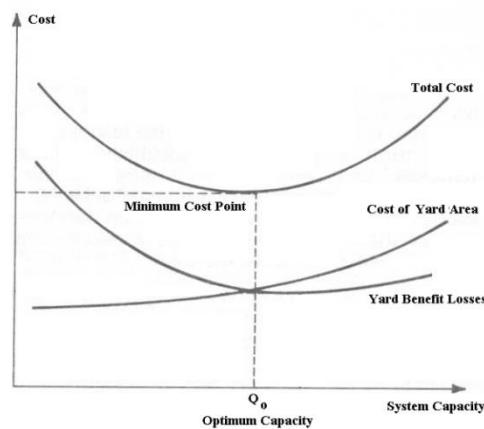


Figure 1. Container Terminal Stock Yard Capacity-cost Function

1.1. Container Storage Area Planning based on Inventory Model

To determine the optimum capacity of a stock area, a model based on the inventory theory was developed [15]. The daily storage area cost is expressed as:

$$C_{ss} = \frac{1}{365} C_{rf} x C_s f_0 Q_0 t_0 \quad (1)$$

where Q_s is the daily container amount at the storage area (TEU/day), and f_0 is the unit area per container box (m^2/TEU). f_0 is considered as $15m^2$ for two, $10 m^2$ for three and $7.5 m^2$ for four-level stacking. C_s is the unit cost of storage area per meter-square (USD/TEU/day). C_{rf} is the annual amortization rate determined with Eq.2 where "r" is the annual interest rate and "N" is the life of the investment.

$$C_{rf} = \frac{r(1+r)^N}{(1+r)^N - 1} \quad (2)$$

If $Q_s > Q_i$, idle cost of container slots are considered with unit costs of idle slots and their holding time in the port with Eq.3.

$$t_0 C_{ss} \sum_{i=1}^s (Q_s - Q_i) \quad (3)$$

Where Q_i shows the container numbers arriving in yard, Q_s is the capacity of container storage area, t_0 is the probable holding time for the containers determined with the historical records of the seaport. In this study, a linear regression analysis was performed to determine the probable handling times for arriving containers considering their quantity. For the case of $Q_i > Q_s$, number of containers arriving will be greater than the storage quantity so that profit lost on terminal stock yard will occur resulting from the delay of service. Similar to the first case, Eq.4 can be implemented for determining the cost of service loss for containers in which C_b is unit cost of lost profits determined with port tariffs.

$$C_b \sum_{i=s+1}^n (Q_i - Q_s) \quad (4)$$

An objective function Eq.5 was found by integrating the total cost containing Eq.3 and Eq.4.

$$C(Q_i, Q_s) = C_b \sum_{i=1}^s (Q_i - Q_s) t_i + C_s \sum_{i=1}^s (Q_s - Q_i) t_i \quad (5)$$

1.2 Container Traffic Projection based on the ANN Model

For implementing the proposed model for the future years, the probable amounts of containers in the storage area must be predicted. For this purpose, an ANN model was used for forecasting the container traffic by considering the economic and demographic parameters.

The ANN is a basic mathematical model of the human brain contains inter-connected neurons to each other[16]. Similar to the human brain, the ANN network is able to recognize the pattern in a data and fit well for nonlinear characteristics of a system. Application of the ANN is a common solution for many engineering problems containing nonlinear systems. Not only, the implementation of the ANN for civil engineering problems such as water resources and hydrology is also applicable but also, it is quite promising in solving the nonlinear, multivariate and complex characteristics of the transportation problems. The ANN consists of several data processing nodes called neurons grouped in several layers called input, output and hidden. A three-layer ANN is shown in Figure 2. Detailed information for the ANN models can be found in [16] and [17].

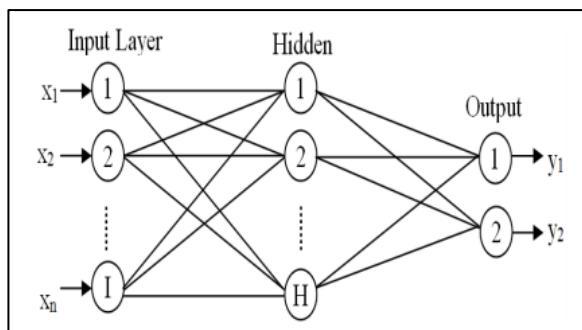


Figure 2. A Typical Diagram of an ANN Structure

After the training process, network performance is evaluated with a validation data considering Mean Square Error (MSE) statistic with the Eq.6.

$$MSE = \frac{(O_e - O_m)^2}{n - 1} \quad (6)$$

where O_e is the expected value, O_m is the predicted value from the model and “n” is the size of the dataset. To achieve an optimal learning performance and avoid overtraining, excessive care must be taken in the modeling progress. Determination of the number of the hidden layer neurons is also a crucial factor influencing the ANN performance as with a high neuron number; training will take considerable time and over fitting of the data is quite possible.

3. Implementation of the Model for the İzmir Seaport

3.1. Information about the Seaport

İzmir seaport, Operated by Turkish General Directorate of State Railways (TCDD), is an important export hub in the western Anatolian region of Turkey [18]. The İzmir city is the third largest city of Turkey with a population over 4 million inhabitants is an important city with its exports corresponds to 6% and imports 4% of Turkey's foreign trade volume[19]. The seaport is connected to the railway and highway networks. Plan and aerial views of the İzmir seaport are shown in Figure 3-a and Figure 3-b.



**Figure 2. (a) Plan and (a) Aerial Views of the Izmir Seaport
(Retrieved from Bookyourtransfer.com)**

3.2 Container Traffic Forecasting

For determining the future berth requirements, the number of arriving ships to the seaport was considered, as the input parameter required being determined with a projection study. For this manner, an ANN model was implemented simultaneously with the linear regression model to check if it is superior to the latter one. A three-layer model represented in Figure 3 was trained with the back-propagation algorithm implemented for this study with the dependent and independent variables. Total ship traffic was used in the output layer. The optimum number of neurons in the hidden layer was determined by trials.

Table 1. Parameters of the ANN for Estimating the Container Traffic

Predictor Variables	Retrieved from	Variable Type
Population	[20]	Predictor
Total Exports	[21]	Predictor
GDP	[20]	Predictor
Total Imports	[22]	Predictor
Ship Traffic	[23]	Target

For the ANN modeling, a normalization procedure is required for the input and output variables[24]. In this study, input and output variables were normalized between 0.1 and 0.9 with Eq. 7.

$$Y_n = 0.9 \frac{Y_r - Y_{r\min}}{Y_{r\max} - Y_{r\min}} + 0.1 \quad (7)$$

where Y_n is the normalized signal, Y_r is the raw signal, $Y_{r\max}$ and $Y_{r\min}$ are maximum and minimum signals in the data set.

As the ANN modeling is out of the scope of this study, results were taken from another study of authors considering the Izmir seaport:[25]. Figure 3. Indicated the results for both the ANN and the Multiple Linear Regression (MLR) models with respect to the total container handling of a seaport until 2023.

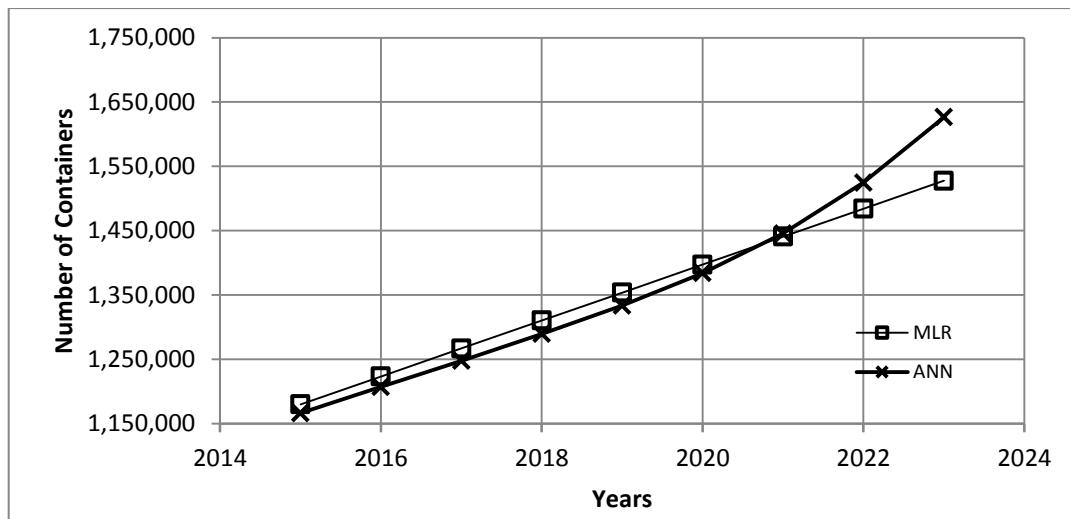


Figure 3.The ANN and the MLR Model Results Showing the Estimated Container Numbers until 2023

The forecasted container numbers were used to correlate the monthly container input with the storage area considering the year 2000. In the scope of the correlation, the total amount of containers handled in the seaport for 2000 was compared with the upcoming years and monthly container input data was multiplied with the corresponding ratio (See Figure 4.).

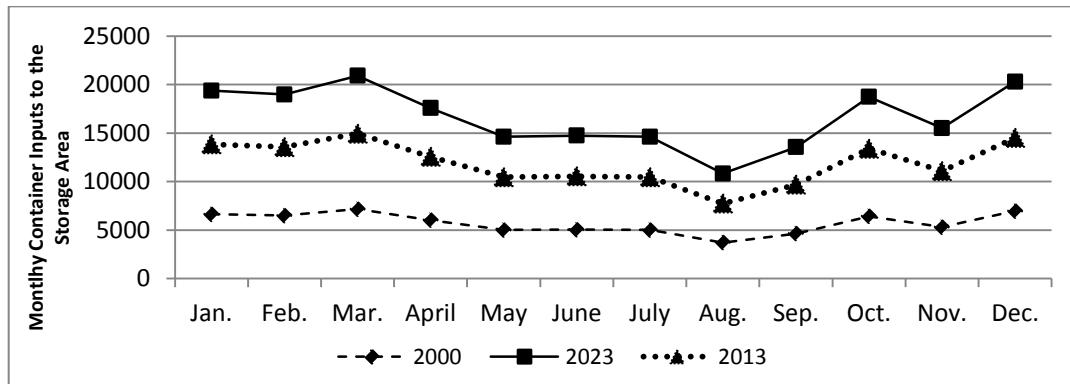


Figure 4. Total Container Handling for Izmir Seaport Considering both LR and ANN Models

3.3 Determination of the Model Parameters

For the analysis, several model parameters were estimated or taken from other sources. Annual interest rate for calculation of the annual amortization rate was taken as 2%. The life of the investment was taken as 10 years. Determination of the storage area cost C_s is accepted as \$0.3/Day/TEU. In addition, C_b was taken as \$40 USD/TEU same as a similar seaport[15]. The waiting time for containers per day was obtained from [26]. The analysis were carried out for $f_0=2$.

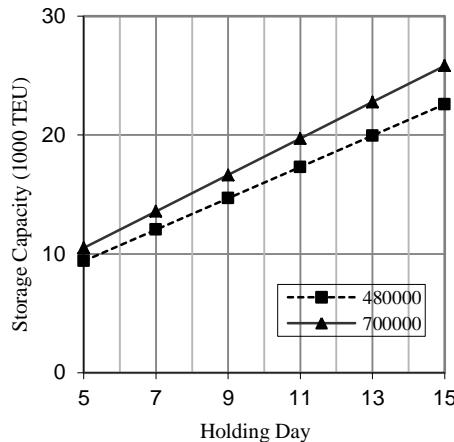


Figure 5. Holding Time versus Handling Capacity[26]

The calculation procedure was performed in the Excel® software considering 24 successive months. For this, monthly container arrivals for successive months were coupled together as 2000-2001, 2002-2003... 2013-2023. The inventory analysis for the yearly-couples was performed considering capacity of 8000 containers to 19000 container with 1000 container increments. The total costs vs. storage capacity for years of 2014, 2018 and 2022 are shown in Figure 6.

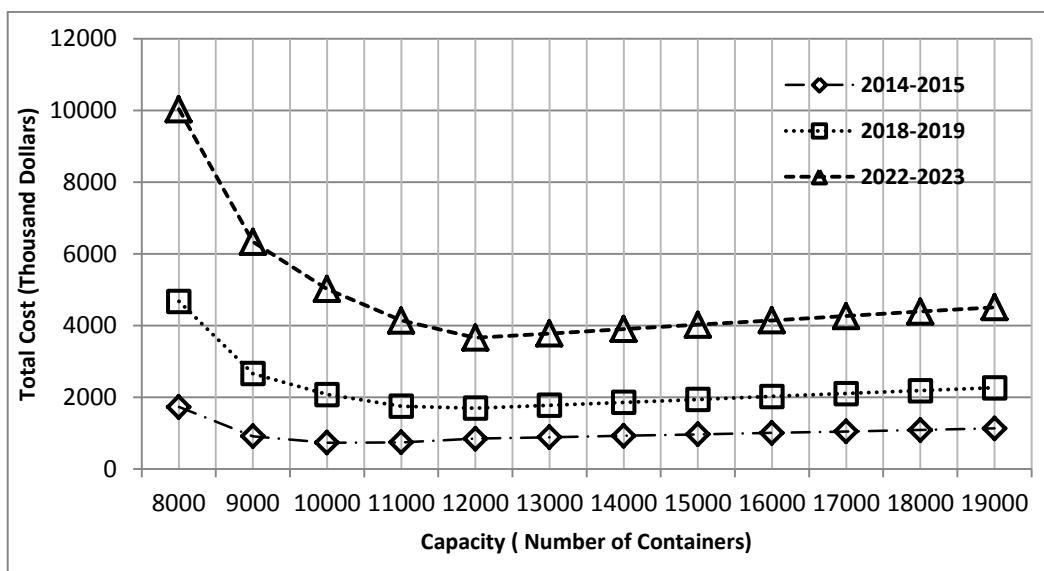


Figure 6. Plot of Total Cost – Storage Area Capacity for Three Distinct Years

4. Conclusion

This study aimed to determine the optimum size of container storage area in Izmir Port, tried to implement both the ANN and the inventory theory to obtain a better forecasting method. The model output of the ANN used to forecast the probable monthly container traffic of the storage area was utilized in the inventory analysis. It was found that, the inventory model can yield outputs for determining the size of storage area at yard. It was also found that, the capacity requirement for an optimal storage area management for the seaport was around 10000 containers for 2014, 11000 for 2018 and 12000 for 2023. As a result, this study indicated that both ANN model and inventory analysis could be implemented for determination of the preliminary capacity analysis of storage area in a

seaport. For a detailed analysis, simulation methods are planned to be implemented for comparing the outputs of this study.

References

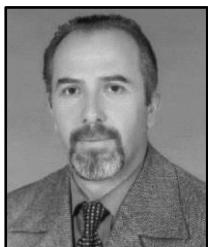
- [1] W. Atkins, "Modern Marine Terminal Operations and Management", Port of Oakland, **(1995)**.
- [2] L. H. Lee, E. P. Chew, K. C. Tan and Y. Han, "An optimization model for storage yard management in transshipment hubs", Container Terminals and Cargo Systems: Design, Operations Management, and Logistics Control Issues, **(2007)**, pp. 107–129.
- [3] P. Chen, Z. Fu, A. Lim and B. Rodrigues, "Port yard storage optimization", IEEE Trans. Autom. Sci. Eng., vol. 1, **(2004)**, pp. 26–37.
- [4] J. J. Wei, "Algorithm to arrange storage locations for export containers in the yard", NCM - 5th International Joint Conference on INC, IMS, and IDC, **(2009)**.
- [5] S. Bassan, "Evaluating seaport operation and capacity analysis—preliminary methodology", Maritime Policy & Management, vol. 34, **(2007)**, pp. 3–19.
- [6] W. H. K. Lam, P. L. P. Ng, W. Seabrooke and E. C. M. Hui, "Forecasts and Reliability Analysis of Port Cargo Throughput in Hong Kong", J. Urban Plan. Dev., vol. 130, no. 3, **(2004)**, pp. 133–144.
- [7] T. Rifat, K. Alp and K. Özen, "Forecasting the container traffic at port of Antalya through fuzzy neural network method", Dokuz Eylül Univ. J. Marit. Fac., vol. 5, no. 2, **(2013)**, pp. 109–120.
- [8] A. M. Goulielmos and E. Kaselimi, "A non-linear forecasting of container traffic: the case-study of the Port of Piraeus, 1973-2008", Int. J. Shipp. Transp. Logist., vol. 3, no. 1, **(2011)**, pp. 72–76.
- [9] W. Seabrooke, E. C. Hui, W. H. Lam and G. K. Wong, "Forecasting cargo growth and regional role of the port of Hong Kong", Cities, vol. 20, no. 1, **(2003)**, pp. 51–64.
- [10] C. C. Chou, C. W. Chu and G. S. Liang, "A modified regression model for forecasting the volumes of Taiwan's import containers", Math. Comput. Model., vol. 47, no. 9–10, **(2008)**, pp. 797–807.
- [11] X. Fanhui, "Container handling capacity prediction model based on RBF neural networks and its simulation", vol. 00, **(2007)**, pp. 1098–1100.
- [12] H. E. Scarf, "Inventory Theory", Operations Research, vol. 50, **(2002)**, pp. 186–191.
- [13] A. Hamdy, "Operations Research: An Introduction", Prentice Hall, **(1997)**.
- [14] F. S. Hillier and G. J. Lieberman, "Introduction to Operations Research", **(1974)**.
- [15] H. Özmen and S. Özen, "Limanlardaki konteyner depolama sahalarının optimum boyutlandırmasına yönelik bir yöntem", III Ulusal Kıyı Mühendisliği Sempozyumu, **(2000)**.
- [16] S. Haykin, "Neural Networks-A Comprehensive Foundation", **(1999)**.
- [17] M. M. Aydin, M. S. Yıldırım, O. Karpuz and K. Ghasemlou, "Modeling of driver lane choice behavior with artificial neural networks (ANN) and linear regression (LR) analysis on deformed Roads", Comput. Sci. -Engineering An Int. J., vol. 4, no. 1, **(2014)**, pp. 47–57.
- [18] World Fact Book, "The World Fact Book : Turkey", [Online]. Available: <https://www.cia.gov/library/publications/the-world-factbook/geos/tu.html>, **(2015)**.
- [19] Turkish Exporters Assembly, "Economy and Foreign Trade Report", **(2014)**.
- [20] TURKSTAT, "titlew", [Online]. Available: <http://www.turkstat.gov.tr/UstMenu.do?>, **(2014)**.
- [21] Ministry of Economy Repubic of Turkey, "2023 Turkish Action Plan of Trade Strategy", **(2010)**.
- [22] IMF, "No Title", [Online]. Available: <http://www.imf.org/external/data.htm>, **(2014)**.
- [23] Ministry of Transport Maritime Affairs and Communications, "Ministry of Transport Maritime Affairs and Communications Database", **(2014)**.
- [24] C. Gershenson, "Artificial Neural Networks for Beginners", Networks, vol. cs.NE/0308, **(2003)**, p. 8.
- [25] M. S. Yıldırım and Ü. Gökkuş, "Estimation of Container Throughput at Ports Using Neural Networks with the Artificial Bee Colony Algorithm", **(2015)**.
- [26] E. Budak, "Optimization of port capacity and storage areas" , **(2002)**.

Authors



Mehmet Sinan Yıldırım, he is currently working as the research assistant at Manisa Celal Bayar University, Civil Engineering Department- Hydraulic Division. Prior to joining Manisa Celal Bayar University, Mr. Yıldırım worked as research assistant at Gumushane University. He is continuing his PhD study in Civil Engineering Department of Manisa Celal Bayar University, Graduate School of Natural and Applied Sciences, Izmir, Turkey. He holds a MSc degree in the Water Resources Engineering from Middle East Technical University and a bachelor's degree in Civil Engineering department from Middle

East Technical University. His current research interests include lane utilization, lane changing, dwell time, bus blockage effect, signalized intersections, Hydraulic Modeling and Soft Computing



Ümit Gökkus, he is currently working as a Professor in the Manisa Celal Bayar University, Civil Engineering Department- Head of Hydraulic Division. He had his PhD degree from Dokuz Eylül University in Turkey and he holds an MSc degree in Civil Engineering Department from the Middle East Technical University and a bachelor's degree in Civil Engineering Department from Akdeniz University. His current research interests include Coastal and Port Engineering, Offshore Pipeline Engineering, Fluid-Structure Interaction and Marine Transportation.

