

The Use of Seasons in Preventing Marine Pollution from Cargo Ships in Laem Chabang Port, Thailand

Chalermpong Senarak*

Faculty of International Maritime Studies, Kasetsart University, Chonburi 20230, Thailand

ABSTRACT

The success of marine pollution prevention relies on several managerial tools and knowledge from the interdisciplinary sciences. As the critical source of pollution, seaports need a variety of policies and practices for enhancing their environmental performance. This paper contributes to the existing literature and the implementation by analyzing the season of operational waste from maritime transportation. The seasonal regression analysis (SRA) was performed by using the data from Port Authority of Thailand. The adjusted model provides a greater statistics for identifying the seasons than that of the original model which was impaired by the obsolete information. To ensure the correctness of the finding, the result of SRA was compared with the seasonal index, goodness-of-fit measure and model error obtained from times series analysis. The conclusion was mutually agreed by two approaches indicating the reliability of the research finding. As the vacillation of operational waste depends on time, port authority should pay a close attention during the high season. Thanks to the enormous amount of operational waste, the monitoring of ship and marine environment should be strictly implemented. However, the pollution-related concern can be alleviated during the interval of the low season due to the scarce demand for discharging operational waste at the port.

Keywords: Season/ Laem Chabang Port/ Operational waste/ Marine pollution prevention/ Seasonal regression analysis/ Time series analysis

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1. INTRODUCTION

Since the early 1970s, there has been a great effort in preventing marine pollution from the operation of seaports (Waldichuk, 1973). Many evidences prove that the activities in port area generate many kinds of pollutant which aggravate multiple problems such as natural degradation, death of aquatic creatures, loss of ecological integrity of the reef, damage of ships, human diseases and loss of recreational place (Laist, 1987; Vauk and Schrey, 1987; Henderson, 2001; Derraik, 2002; Butt, 2007; Hinojosa and Thiel, 2009; Ngand Song, 2010; Ulnikovic et al., 2012; Lam and Notteboom, 2014; Senarak, 2014; Phillips, 2015). Recently, the concern about pollution from seaport operation increases due to the rapid growth of trade and maritime transportation in many economies (Caesar, 2010; Lam and Notteboom, 2014). With this reason, the International Maritime Organization (IMO) has encouraged all port authorities, especially of IMO's state members, to ensure their environmental standards as well as enhance their ability to prevent marine pollution from different kinds of waste, including ship-generated garbage, in and around port area (Knapp and Franses, 2009).

Apart from the adequate provision of garbage reception facility (GRF), the additional managerial measures and tools are still required for seaports because it was explored that laws and regulations, which are the major tools of IMO, were ignored by many ship operators; they intended to illegally dump ship-generated garbage into the ocean (Horsman, 1982; Olson, 1994; Cho, 2009; Chen and Liu, 2013). On one hand, IMO has

launched a series of conventions and guidelines in order to solve this problem; for example, the International Convention for the Prevention of Pollution from Ships (MARPOL convention) (International Maritime Organization, 2002), the guidelines for ensuring the adequacy of port waste reception facilities (International Maritime Organization, 2000) and the guidelines for the implementation of MARPOL Annex V (International Maritime Organization, 2012). In addition, several scholars took a great effort in developing means for coping with pollution from sea transportation such as Cho (2009) and Chen and Liu (2013) who recommended implementing the incentive scheme, education and use of recyclable items in order to lessen the unlawful discharge of garbage into the sea. Contrarily, Lam and Notteboom (2014) argued that by monitoring, measuring as well as a discount of green tariff can persuade the shipping lines to diminish the pollution, especially GHG emission from vessels, from their fleet. Practically, packs of tools are entirely implemented in every port, especially in the leading ports at which marine traffic is intensive such as the port of Singapore, Shanghai, Antwerp, Busan, and Rotterdam.

Likewise worldwide ports, Laem Chabang port (LCP) is encountering with the environmental challenge. It was reported that a hundred of ships berthing at LCP dumped their garbage into the sea, causing the accumulation of marine debris along the coastal line of Chonburi province (Nomsin, 2007). This did not only worsen the marine ecosystem, but also exacerbated the living of residents in Laem Chabang Municipal and the

*Corresponding author:

E-mail: chalermpong.s@ku.ac.th

other areas nearby. Thus, Port Authority of Thailand (PAT) has given a great attempt at strengthening the environmental standards through the cooperation with the international institutes. For instance, the cooperation with Partnerships in Environmental Management for the Seas of East Asia (PEMSEA) for the technical assistance in the orientation of Port Safety, Health, and Environmental Management System (PSHEMS); the cooperation with ASEAN Ports Association (APA), German International Cooperation (GIZ) and PEMSEA for the implementation of the Sustainable Port Development in the ASEAN Region (Apai and Thammapredeedee, 2012). At this day and age, many programs arranged by LCP and partners are being implemented; for example: 1) green port program (GPP) which aims to address the carbon dioxide emissions by using green energy like electricity in port; 2) low carbon port program (LCPP) that needs to encourage all private terminal operators to switch their fuel consumption from diesel fuel to electric power; and 3) Natural Resources Conservation (NRC) which aims to urge the community to participate in the activities held by LCP such as collecting garbage and monitoring sea water quality and so on.

Nevertheless, marine pollution in port still remains and the quality of sea water in LCP area has been gradually worse from year to year (Pollution Control Department, 2013). Moreover, the trust of the community in Laem Chabang municipal seems to be continuously dwindled by the negative externality from ports' operation. This situation can interrupt the development plan in the future like Phase-3 construction which is the port extension plan of PAT. Furthermore, the management of the GRF in LCP lacks the knowledge support from scholars' research except the work of Senarak (2016) who developed the econometric tool for enhancing the operational waste management of PAT. Hence, this paper contributes the existing literature by originally developing the knowledge body of by what means to use the season of waste to enhance the ports' ability in preventing pollution from sea transportation and assists the practitioners by providing the policy implication for the GRF management in different seasons. The seasonal regression analysis (SRA) with ordinary least square technique (OLS) was used to investigate whether the amount of operational waste depends on time during the year. Furthermore, the result of SRA was compared with that of time series analysis in order to ensure the reliability of the finding. The paper was organized into three main sections: 1) research background and methodology; 2) results and discussion; and 3) policy implication and suggestion for the future study.

1.1 Operational waste as described in Annex V of MARPOL 73/78

The operational waste is defined as the garbage generated from the routine operation of vessels' engine room where the main engine and other auxiliary engines are installed. The operation of the main engine is normally driven by fuel bunker which generates various

types of waste such as carbon ash, smoke, residue CO₂, SO₂, NO_x, PM₁₀, PM_{2.5}, HC, CO and VOC (Lam and Notteboom, 2014; LR, 2014). The leakage from engine operation also originates oily stain, lubricant dirt and gas blur which is normally removed by the rag. The fluorescent and light bulb are other kinds of operational waste which harms marine environment due to Mercury composition. Therefore, all types of operational waste must be stored separately from ordinary garbage and kept onboard the ship throughout the trip. The discharge of operational waste into the sea is prohibited by MARPOL convention. Those ships that break the laws might be detained by port state control until the environmental standards of the ships are maintained (Ball, 1999; International Maritime Organization, 2002; LR, 2014).

1.2 Location of study

Laem Chabang Port (LCP) is the international container port located on the east coast of the Gulf of Thailand. It covers approximately 2,572 acres including the coastal area of 4.5 acres which is the home of fauna and flora species (Apai and Thammapredeedee, 2012; Laem Chabang Port, 2014). Almost 80% of total container cargoes throughout the country pass LCP; hence, it becomes the major port which drives the economic growth of not only the nation, but the region (Laem Chabang Port, 2014) (World Bank Group, 2014). Annually, more than 10,000 of vessels from worldwide ports berth at LCP. The number of ship doubles from 6,107 ships in 2008 to 11,974 ships in 2014 and the marine traffic increases from 4.549 million trips in 2010 to 4.841 million trips in 2011. Besides break-bulk vessels, the other types of ship can be explored in the operation area of LCP such as chemical tankers, LNG tankers, and chemical/oil product tankers, domestic and coastal ships, barges, offshore supply vessels, military ships, the US royal navy vessels, safeguard-class rescue, and salvage ships etc. (Apai and Thammapredeedee, 2012; Laem Chabang Port, 2014).

During the year, the operational waste is mainly discharged from four types of cargo ship-container ship, Ro-Ro vessel, general cargo ship and bulk carrier. It is normally comprised of contaminated fabric, contaminated container, material scrap, and fluorescent lamp which are prohibited to be disposed into the sea. In order to manage this waste appropriately, LCP provides garbage reception facility (GRF) including: 1) medium-size shed with four storage spaces for different types of waste and a large space for sorting operation; 2) three garbage-collecting trucks which can be used interchangeably; 3) two labors working on truck; and 4) one to two labors at the sorting shed. For those who demand to use the GRF of LCP, they are required by Port Authority of Thailand (PAT) to submit their request forms 24 h prior to the arrival of the ship. The service will normally be confirmed by the shipping agents via a telephone call. If the garbage-collecting truck is not available or the due date is in the holiday period, ships have to wait until the working days. Alternatively, they can pack their garbage in a plastic bag and then leave it at the garbage bin in the terminal area.

The operational waste will be sorted out from the ordinary garbage and stored at the shed for fifteen days on average before being removed by the private contractor who is responsible for weighing and recording

it (Marine Department, 2008; Civil Engineering Division, 2015). The amount of operational waste from 2008 to 2014 is plotted in Figure 1.

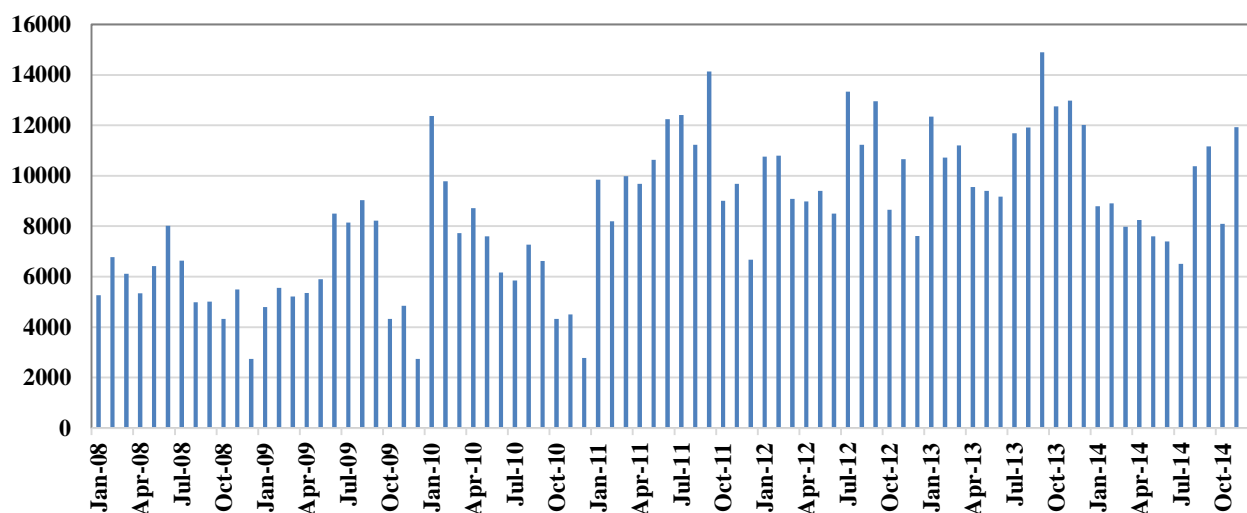


Figure 1. The amount of operational waste delivered at Laem Chabang Port (kg/month), as from 2008 to 2014

Corresponding with Figure 1, the amount of operational waste discharged from cargo ships at Laem Chabang Port presented an upward trend with a high fluctuation over the past seven years.

2. METHODOLOGY

2.1 Data collection

The statistics of operational waste from 2008 to 2014 was obtained from the database of Port Authority of Thailand (PAT). The amount of operational waste is a monthly data and measured in the kilogram. The validation of data was verified by three means. Firstly, the data recorder and his supervisor from PAT were asked to investigate the correctness of data; and it was explored that all records were valid. Secondly, the statistical technique was used to detect whether there is any outlier in the dataset. The descriptive statistics illustrated that there was no outlier. Finally, the data was rechecked by three experts - the specialist in: 1) maritime study; 2) marine transportation; and 3) econometric from Marine Department and educational institutes, and the validity of data was agreed by all specialists.

2.2 Methods

2.2.1 Graphical method

The graphical technique (line chart) was performed in order to visually analyze the general relationship between variables. The monthly amount of operational waste was plotted on the vertical axis against time (month) during the year in the horizontal axis. This method can be used to initially detect the season of operational waste.

2.2.2 Seasonal regression analysis

The seasonal regression analysis (SRA) was conducted in order to explore the season of the

operational waste which was delivered from cargo ships from 2008 to 2014. The analysis was based on the assumption that the amount of operational waste (dependent variable) depends on time (month) during the annum (explanatory variable). The former is the ratio scale variables whereas the latter is the nominal scale variable. Hence, it was represented by dummy variables (0, 1) in SRA. The mathematical relationship between variables in SRA was formulated in equation (1).

$$y_i = \beta_0 + \beta_1 D_{1i} + \beta_2 D_{2i} + \beta_3 D_{3i} + \beta_4 D_{4i} + \beta_5 D_{5i} + \beta_6 D_{6i} + \beta_7 D_{7i} + \beta_8 D_{8i} + \beta_{10} D_{10i} + \beta_{11} D_{11i} + \beta_{12} D_{12i} + \mu_i \quad (1)$$

Where y_i is the amount of operational waste from ships and β_0 is the intercept coefficient. β_1 - β_{12} are the coefficients of variable D_{1i} - D_{12i} whereas μ_i is the stochastic variable. September ($\beta_9 D_{9i}$) is dropped as it is the benchmark of the model.

2.2.3 Time series analysis

In order to ensure the correctness of the result obtained from seasonal regression analysis (SRA), the time series analysis was used to recheck the seasonality of the operational waste from 2010 to 2014. The exponential smoothing method was calculated by six approaches with different assumptions: 1) simple model which hypothesizes that the amount of waste neither has trend nor season; 2) Holt's model; 3) Brown's linear trend; 4) damped trend which assumes that there is no season except trend; 5) simple seasonal model which hypothesizes that there is the only season without trend; and 6) Winters' method which is separated into two sub-models: 6.1) additive model; and 6.2) multiplicative model which postulates that there are both season and trend. Moreover, the seasonal factor was also analyzed by

seasonal decomposition, which was used to detect the influence of season on the variation of operational waste.

3. RESULTS AND DISCUSSION

3.1 Result of graphical technique

The mean value of operational waste per month as calculated and then plotted on the vertical axis against time (month) on the horizontal axis, as presented in Figure 2.

According to Figure 2, September has the highest amount of operational waste at garbage reception facility

(GRF). As a result, it is specified as the benchmark (the highest season) of the seasonal regression model (SRA). Afterward, the quantity of operational waste tends to drop until December when there is the lowest operational waste at the GRF. Thus, it is more likely to be a low season. However, the season from January to June is somewhat difficult to be identified as it presents a moderate trend. To clarify this ambiguity, the SRA was performed in the next iteration.

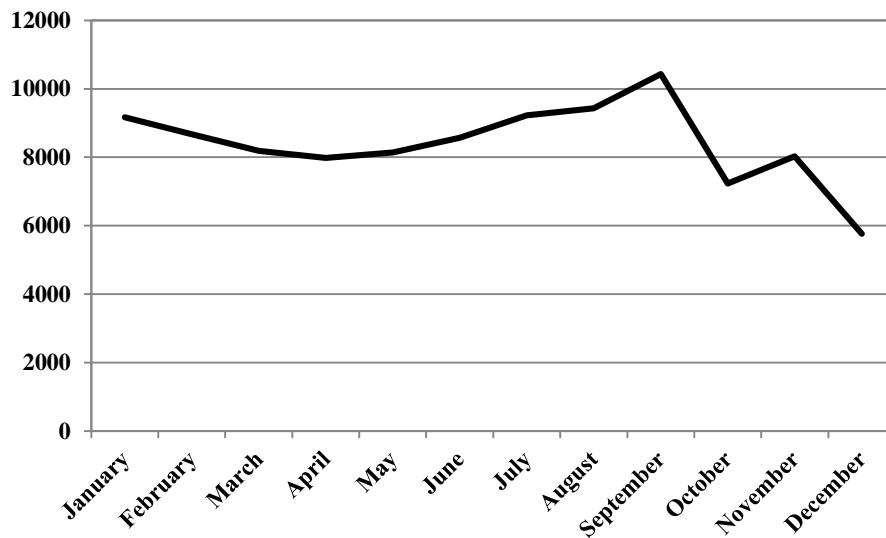


Figure 2. The average amount of operational waste per month over seven years (kg/month)

3.2 Result of seasonal regression analysis

According to equation (1), the amount of operational waste was run against time (month) during the year from 2008 to 2014 by seasonal regression

analysis (SRA) with the ordinary least square technique (OLS). The result of the original model was presented in Table 1.

Table 1. Result of seasonal regression analysis

Variable	Original model		Adjusted model	
	Coef.	Std. Err.	Coef.	Std. Err.
January	-1262.71	1508.79	-2851	1336.252**
February	-1752.85	1508.79	-3633.5	1336.252***
March	-2244.14	1508.79	-3728.5	1336.252***
April	-2447.14	1508.79	-4173.5	1336.252***
May	-2293.57	1508.79	-4031	1336.252***
June	-1860	1508.79	-3961	1336.252***
July	-1204.57	1508.79	-2302.75	1336.252*
August	-998	1508.79	-2103.75	1336.252
September	Dropped	Dropped	Dropped	Dropped
October	-3197	1570.4**	-3663.25	1336.252***
November	-2403.33	1570.4	-1978.5	1336.252
December	-4669	1570.4***	-3264.5	1336.252**
Constant	10430		13288.5	

***= significant at 1%, **= significant at 5%, *= significant at 10%

3.2.1 Result of the original model

According to Table 1, the slope coefficients of the variables refer to the difference between its mean value and that of the benchmark which is represented by the intercept coefficient. However, it is noticed that the only two months that are significantly different from September are October (sig. at $\alpha=5\%$) and December (sig. at $\alpha=1\%$). Therefore, December can be clearly

classified as the low season whereas October, which is slightly lower than September, can be sorted as the moderate season.

It is noted that the power of seasonal identification of the original model that is very low might stem from the distinction of the data. To initially inspect the assumption, the annual amount of operational waste was plotted as the line chart in Figure 3.

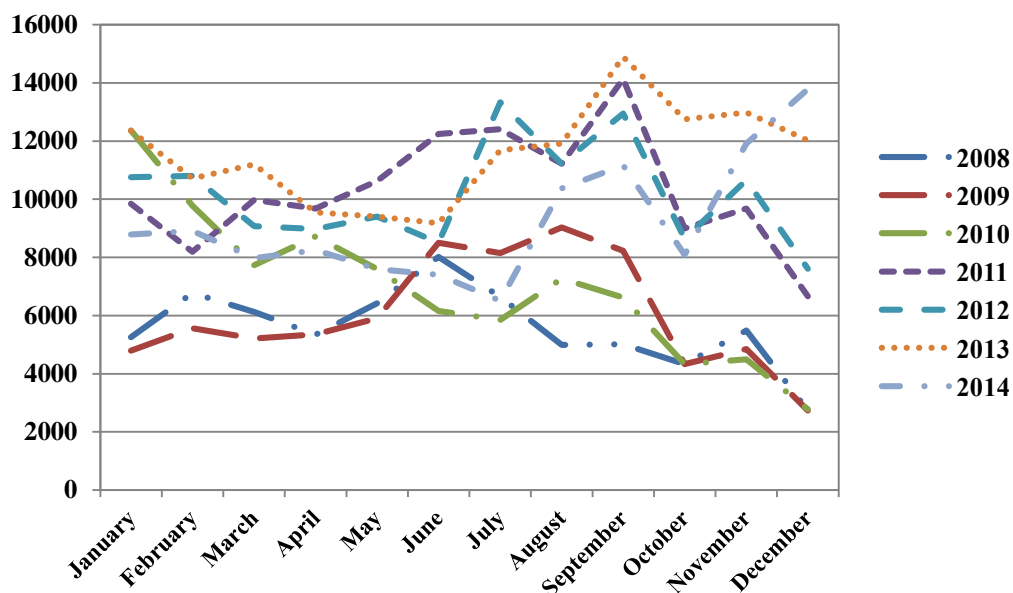


Figure 3. The monthly amount of operational waste from 2008 to 2014 (kg/month)

According to Figure 3, the general trend of the line charts of seven years looks similar. However, the range of mean value in the similar month is so high that it might impair the ability of the seasonal regression analysis (SRA) to identify the season. To statistically examine the influence of the difference of data, the t-test was used to compare the mean value of the operational waste between two groups: 1) the former group (2008-2010); and 2) the newer group (2011-2014). The result indicates that the data of the former group is significantly lower than that of the newer group at $\alpha=0.05$ ($p < 0.000$). It is implied that the initial expectation is true. Thus, the data from 2008 to 2010 was left from the dataset in order to eliminate the influence of the obsolete data. Afterward, SRA was conducted and the result of adjusted model was presented on the right of Table 1.

3.2.2 Result of the adjusted model

According to the result in Table 1, the huge improvement was explored in term of season-identification power. August and November can be obviously considered as the high season because they are not significantly different from September which is the highest season of the annum whereas the low season can be February, March, April, May, June and October, respectively since they indicate statistically significant

difference from the base month. For July, the test shows that it is significant at $\alpha=0.1$ implying that it is almost insignificant from the high season. Moreover, the t-test shows an insignificant difference between July and August ($p=0.903$); therefore, July can be identified as the moderate high season. On the other hand, January and December are significantly different at $\alpha=0.05$; as a consequence, they can neither be grouped as low nor high season. However, the t-test tells that January is significantly closer to February ($p=0.463$) than August ($p=0.396$); hence, it should be sorted as the moderate low season. By using the same technique, December can be classified into the similar group as January because it is significantly closer to February ($p=0.847$) than August ($p=0.530$). According to above discussion, it can be concluded that the amount of operational waste depends on time (month) during the annum and its fluctuation is dominated by season, as illustrated in Figure 4.

3.3 Result of time series analysis

To confirm the conclusion of the seasonal regression analysis; the results obtained from seven approaches of time series analysis; the goodness-of-fit measure and the accuracy of forecast; were used to analyze the influence of season on the fluctuation of operational waste, as presented in Table 2.

Table 2. Model statistics, based on the data from 2010 to 2014*

Method	Statistics			
	R-squared	RMSE	MAPE	MAE
Simple exponential smoothing	0.276	2142.681	18.970	1694.023
Holt's linear trend	0.276	2160.852	19.279	1708.267
Brown's linear trend	0.164	2302.240	17.977	1695.659
Damped trend	0.279	2175.611	18.642	1673.109
Simple seasonal	0.554	1695.988	13.624	1247.045
Winters' additive	0.561	1697.726	13.426	1223.979
Winters' multiplicative (Y=square root form)	-0.011	2576.041	24.355	2094.033

* Data from 2011 to 2014 cannot be used to calculate R-squared because of the scarcity of the data series.

The result in Table 2 shows that the Winters' additive method provides the best statistics with the highest R^2 of 0.561 and the lowest mean absolute percentage error (MAPE) of 13.426. This implies that the operational waste seems to have season and trend. This corresponds to the assumptions of Winters' additive method. Likewise, the simple seasonal method also provides a great result but its statistics is worse than the Winters' additive method because the influence of trend is not assumed. Contrarily, the rest methods, which have no season assumption, indicate the much lower goodness-

of-fit measure with the high error. This indicates that simple exponential smoothing, Holt's linear trend, Brown's linear trend and damped trend do not fit with the dataset of operational waste. Unlike other approaches, Winters' multiplicative seems to encounter with the mathematical problem due to the form of data (square root) which impairs the ability to compute the R^2 . To further analyse the influence of season, the seasonal factor was computed by seasonal decomposition and the result was presented in Table 3.

Table 3. Seasonal factors, based on data from 2011 to 2014

Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seasonal factor (%)	110	105.6	92.1	92	87.8	84.2	111.1	113.8	137	87.9	104.2	74.4

The seasonal factor in Table 3 reveals that the annum begins with the moderate low season and then the low season continues over the next five months. In July, the operational waste dramatically increases from the previous month and holds on the upward trend until September which is the highest season of the year. After that, the high fluctuation occurs over the next three months and, at the end of the year, it is the commencement of the low season. Therefore, due to the large difference of the seasonal factor between September (137) and December (74.4), it can be summarized that there is the dominance of season on the vacillation of operational waste during the year.

In accordance with the aforementioned discussion in 3.1-3.3, the variation of operational waste at garbage reception facility of Laem Chabang Port is dominated by season which can be depicted as the chart in Figure 4.

Corresponding with Figure 4, the high season commences in July and continuously increases until it reaches the highest point in September. In this period, the management of operational waste should be carefully paid attention by the port authority and the other related organizations because the high season implies a large amount of operational waste discharged from a number of the ships at the Garbage Reception Facility (GRF). It is likely for the GRF to be unavailable to serve all requests of the shipping lines and agents. The facilities of the port such as the garbage-receiving truck, sorting area and storage spaces in the shed are possible to be overloaded

due to the high demand. This situation can result in an increasing waiting time, loss of money, delay of ships and unnecessary energy consumption of ships etc. Hence, the illegal discharge of operational waste into the sea tends to occur in this period rather than other intervals. To remedy this challenge, the authority should prepare the effective garbage management plan and make the GRF ready all the time in order not to discourage the ship operators. The urgent plan should be prepared in advance. The comfortable channels for ship agents to access the information regarding the GRF service should be deployed such as call centers and online information. Moreover, as the shippers and sea carriers are very sensitive to the lead time, the velocity of the GRF provision should be improved which, at the same time, results in an increasing supply of the GRF. For example, boosting of speed might enable a truck to receive more garbage from 10 times to 15 times per day. Besides, port authority should strictly investigate the garbage management plan or garbage record book on board the suspected ships so that risky conduct would be monitored or eliminated. The unseaworthy ships and the polluters should be detained until the environmental standards are maintained in order to ensure the stability of the marine environment.

After the highest season in September, the amount of operational waste rapidly decreases in October and then slightly increases in the next month. Then, the moderate low season begins in December and;

thereinafter, the low season lasts over the next two-quarters. Theoretically, the environmental concern can be relieved in this period because the amount of the operational waste at the GRF is relatively low. The GRF seems to be available to receive the operational waste from every ship without undue delay to ship regular operation. Therefore, the illegal dump of garbage into the sea is less likely to occur in the low season. Port authority might explore the ways to increase the utilization rate of the GRF. The allocation of port resources might be performed through the cooperation with the private terminals and the other ports. For instance, the truck or the sorting shed might be shared with the operation of

garbage that is produced from the terminal operation. The available labors might be allocated to temporarily assist the work of other departments. Nevertheless, this allocation is difficult to be implemented in practice due to the fact that the duty of the GRF is to receive all kinds of waste from all ships without undue delay to the routine operation of the ship. Based on this function, the GRF needs to stand by for every situation, especially for the uncertainty that might take places such as the failure of the garbage-collecting truck or the hasty sick leave of labor which results in the inadequacy of the GRF. As a result, the allocation of the GRF might be oriented with a special caution.

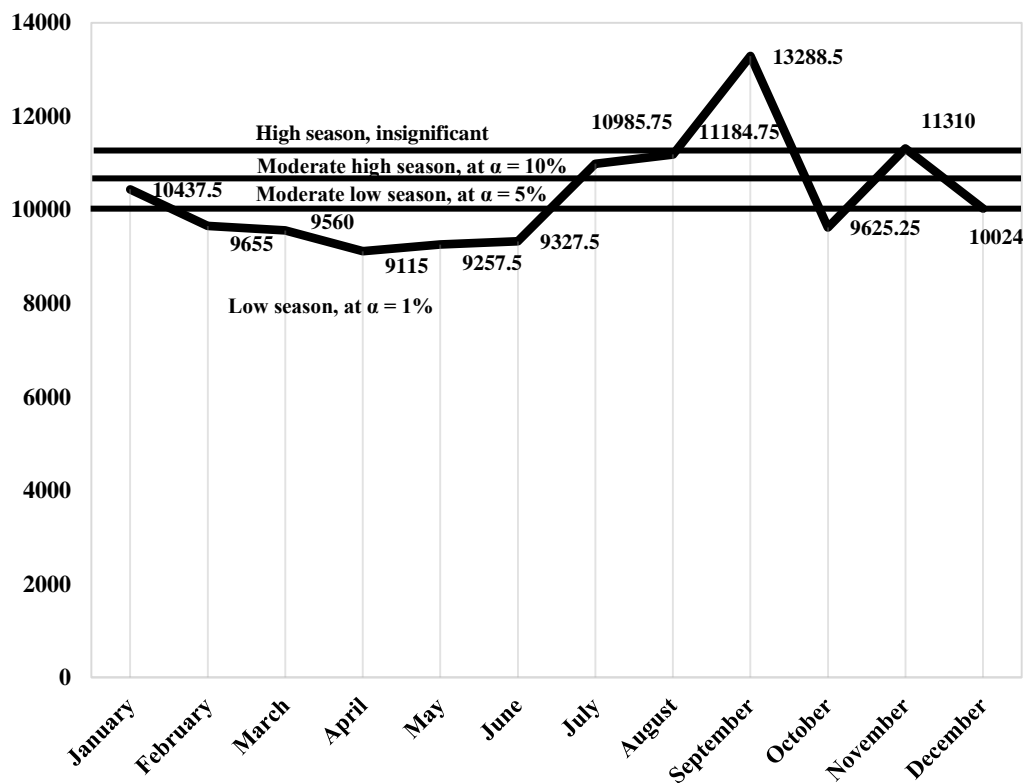


Figure 4. The season of operational waste (kg/month)

4. CONCLUSIONS

Over the past decades, seaports have been seen as the marine polluter and the sea preventer at the same time. Many attempts were given by scholars and practitioners in exploring the tools for dealing with the ship-generated waste in port. A number of policies such as rewarding scheme, education, and the discount of a tariff have been the favorite tools used by many leading ports in order to enhance their green operation. Likewise, Laem Chabang Port (LCP) is encountering with the same challenge. Due to an increasing amount of operational waste and maritime traffic, Port Authority of Thailand (PAT) has tried to strengthen the environmental management policy through the cooperation with many international institutions. To support this goal, the paper originally develops the knowledge of by what means to use season of garbage in preventing marine pollution from sea

transportation in the port area.

The seasonal regression analysis (SRA) was used to investigate whether the fluctuation of operational waste depends on time during the year or not. The statistics of the original model was impaired by the out-of-date information; as a consequence, it was unable to classify the season. To solve this problem, the adjusted model was created by excluding the obsolete data from the dataset. The large improvement was explored and the season can be easily identified. Besides, the result of SRA was compared with the seasonal factor, goodness-of-fit measure and model error which are the outputs of time series analysis. It was found that that the results of two approaches are similar implies the reliability of the finding. Port authority was suggested to implement an intensive monitoring on the suspected ships in order to prevent them from the unlawful conducts during the high

season while the pollution concern can be alleviated due to the low amount of operational waste in port. To further improve the ability of seaports in preventing marine pollution, the additional topics such as the collaboration among stakeholders in dealing with garbage, by what means to develop the tools to control the pollution in port, in what way to convince ship operators to take care of marine pollution and so on are the real challenges for the future study.

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