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Statistical Analysis of Maritime Traffic Volume at Manila Bay, Philippines

Orlando S. Dimailig*† · Jae-Yong Jeong**
* Graduate School, Mokpo National Maritime University, 571 Chukkyo-dong, Mokpo, 530-729, Korea,
** Mokpo National Maritime University, 571 Chukkyo-dong, Mokpo, 530-729, Korea

필리핀 마닐라만의 해양 교통량 통계분석

올란도 디마일릭*† · 정재용**
* 목포해양대학교 대학원, ** 목포해양대학교

Abstract : *Manila Bay is home to the Port of Manila with three harbors: North Harbor, South Harbor and MICT(Manila International container Terminal). There is an adjacent fishing port to the north and another port across the Bay, the Limao Port. This study focuses on the volume of traffic movement in the Bay area taken from Manila VTMS raw data of the arrival and departure movements only. It is a two-year period of study of 2010 and 2011 traffic volume. It divides the data according to their numbers; to their sizes measured in gross tons; to the time of vessels' movements, whether daytime or night-time; and to each voyage trade: domestic or foreign. Quantitative values are calculated from the raw data based on the whole population of the two-year period. The results are illustrated by tables and graphs. Statistical measures are applied to determine the spread and frequencies of the data and test any significance from the hypotheses. These are shown in the tabulated form and interpreted to give a better picture of the frequency and volume of traffic. In the end, a summary is offered where it is hoped that this paper will propel further studies of improving the safety behavior in the premier port of the country.*

Key Words : *Manila VTMS, Manila Bay, Traffic volume, Daytime traffic, Night-time traffic, Statistics*

요 약 : 마닐라만은 3개의 항구가 있는 마닐라항의 집과 같다: 북항, 남항 그리고 MITC. 북항 부근과 마닐라만을 가로질러 리마오라는 어항이 있다. 이 연구는 마닐라만에서 마닐라 VTMS 원 데이터의 입출항 교통량만을 기준으로 교통량의 움직임에 집중한다. 이는 2010, 2011년 2년 동안의 교통량이다. 데이터의 표시를 교통량의 숫자로; G. T.에 의한 크기로; 낮이든 밤이든 선박 동향의 시간으로; 각 국내와 국외 각 항차 거래로 나뉜다. 양적인 수치는 모든 개체군을 기반으로 한 원 데이터로부터 계산된다. 그 결과의 수치는 통계상의 측정된 표와 그래프에 의해 나타난다. 산술평균은 개체군의 변동계수와 표준편차가 요약된 형태로 보여지는 것을 의미한다. 그렇기 때문에, 그것들은 교통량의 빈도와 양의 더 나은 그림을 보여주기 위해 해석된다. 끝으로 본 연구가 필리핀의 가장 중요한 항구의 안전성 향상에 기여하기를 기대한다.

핵심용어 : 마닐라 VTMS, 마닐라만, 교통량, 주간교통, 야간교통, 통계치

1. Introduction

This paper studies the traffic movements of marine vessels at Manila Bay in a two-year period(2010～2011). The data were sourced from Manila Vessel Traffic Management System(Manila VTMS, 2011). The data include the arrival and departure traffic movements only. Other movements like shifting between ports, to-and-fro anchorages, etc. were excluded. The data collected were tabulated or graphed according to volume of vessels, to the sizes in gross tons, to the period of time they were moving, whether during daylight hours or during the night, and lastly, according to the voyage or trade types-domestic or foreign.

The objective of the study is to analyze the maritime traffic movements at the premier maritime port of the country. It also aims to initiate more comprehensive studies of the Bay area for the purpose of identifying the risks and make it more safe and compliant to global standards.

Manila Bay is a natural harbor strategically located at the

† Corresponding author : dimailig_82@yahoo.com, 010-4034-0016

southwestern coast of the main island of Luzon along the capital city of the Philippines.

The Manila Bay's entrance is 10 NM and expands to a width of 26 NM. It is home to the Port of Manila and its three harbors, Figure 1. The three harbors are shown in Figure 2. The main international port is Manila South Harbor, enclosed by a low breakwater.

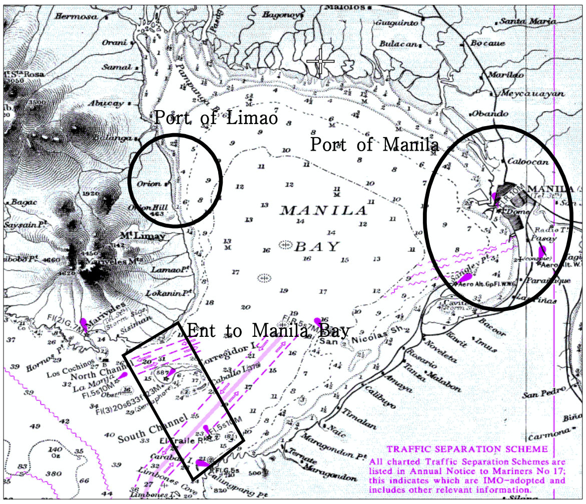

Fig. 1. The Manila Bay showing the Port of Manila Limao Port and Entrance to the Bay.

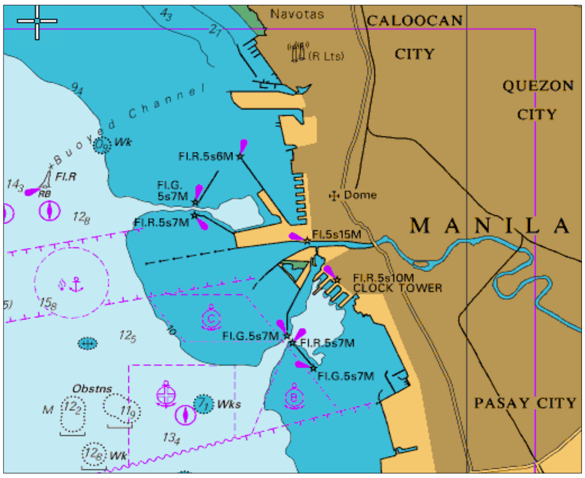

Fig. 2. The Port of Manila with its three harbors: North Harbor, South Harbor and the MICT.

The North Harbor, used for inter-island shipping is a commercial and major transportation port. The Manila International container Terminal(MICT) is the third in the Port of Manila system. Adjacent northward is the Navotas Fish Port. Across the Bay is the port of Limao at the province of Bataan.

2. Maritime traffic movements

Being the premier port of the country, Manila Bay is the center of maritime transportation and commerce. Based on the Philippine Ports Authority(PPA)(2010) data, the total number of portcalls was 14,719 vessels combined with the three harbors. However, the raw data used in this study was taken from Manila Vessel Traffic Management System(VTMS) from a two-year period(2010-11) and were collected by electronic navigational equipment, AIS and other tracking means.

The Bay, however, is the home for numerous types of sea-crafts. They are small motor bancas, others are wooden-hulled and some are motor outriggers ferrying passengers back and forth between neighboring islands that rely on traditional navigational skills and not aided by electronic means(Dimailig et al., 2011).

These sea-crafts are not fitted with AIS or any tracking devices, hence, they are not detected by VTMS equipment and could not be included in this study. However, they ply the Bay regularly and also make up the totality of maritime traffic volume of the Bay.

This section shows the movements of vessels during day and at night, domestic and foreign ships, and the different sizes in gross tons. The basis was from the arrival and departure data while other movements like shifting between ports, to-and-from anchorages, etc. were excluded.

2.1 Statistical methods

The Manila VTMS traffic data were collected, tabulated, graphed and presented quantitatively. They were analyzed by statistical methods and the values gathered were interpreted. The methods are mostly parametric since the whole data of the inclusive years, 2010 and 2011, were used(Calmorin et al., 2004; Frany et al., 2004).

The computations show the arithmetic means, population standard deviation and percentile of each group. In other areas, the population correlation-coefficient was used to correlate the values of daytime and night-time movements. The formulas in this study are:

a. Correlation coefficient

$$r_{xy} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

where :

r_{xy} = *correlation between x and y*

X = *sum of X values*

Y = *sum of Y values*

XY = *sum of product of X and Y*

N = number of cases
X^2 = sum of squared X scores
Y^2 = sum of squared Y scores

b. Chi-Square Test

$$x^2 = \Sigma \frac{(Obs - Exp)^2}{Expected}$$

where :
Obs = Observed frequency
Exp = Expected frequency

c. Z-Test

$$Z = \frac{\tilde{x}_1 - \tilde{x}_2}{SD_1 + SD_2}$$

where :
$\tilde{x}_1$ = Mean of the 1^{st} group
$\tilde{x}_2$ = Mean of the 2^{nd} group
SD_1 = Std Deviation of the 1^{st} group
SD_2 = Std Deviation of the 2^{nd} group

2.2 VTMS Traffic volume data

2.2.1 According to the number of vessels

Figure 3 is the graph for the year 2010 and 2011 volume of ships moving in the Bay area each month. With little variations, it showed less volume of traffic in the earlier months of January and February where it continued to rise till the end of each year. In 2011, the peak month was at 1st to 2nd quarter while in 2010, it was at the 3rd quarter of the year.

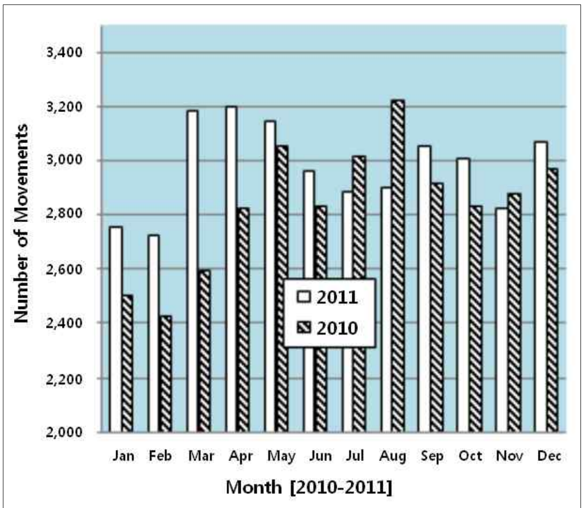

Fig. 3. The volume of vessels per month.

The graph shows that the spread is binomially non-symmetrical for both years. This means that the shipping movement were more frequent from the 2nd to the last quarter of the year.

2.2.2 According to size in gross tons(GT)

Moving vessels were grouped into different sizes according to their gross tonnages: less than 100 GT, between 100 to 500 GT, 500 to 1,000 GT, 1,000 to 5,000 GT and vessels with gross tons more than 10,000 GT. These were tabulated in Tables 1 and 2 below and also show the means, standard deviation and percentile point measures of each group.

Table 1. The 2010 data per month and GT

2010	<100	100-500	500-1K	1-5K	5-10K	>10K	Total
Jan	122	792	339	512	323	422	2,510
Feb	109	820	317	458	323	408	2,435
Mar	140	897	296	536	314	417	2,600
Apr	140	1,125	277	513	318	457	2,830
May	147	1,207	304	558	356	491	3,063
Jun	175	939	331	552	370	473	2,840
Jul	161	1,141	359	551	347	460	3,019
Aug	213	1,177	336	615	376	508	3,225
Sep	168	964	368	563	387	471	2,921
Oct	189	811	429	568	393	451	2,841
Nov	217	873	460	509	377	445	2,881
Dec	145	979	442	569	396	448	2,979
Total	1,926	11,725	4,258	6,504	4,280	5,451	34,144
Mean	161	977	355	542	357	454	2,845
Percentile	5.6	34.3	12.5	19.0	12.5	16.0	100.0

Table 2. The 2011 data per month and GT

2011	<100	100-500	500-1K	1-5K	5-10K	>10K	Total
Jan	164	828	440	522	369	432	2,755
Feb	128	976	395	505	301	419	2,724
Mar	229	1,103	417	606	325	502	3,182
Apr	218	1,095	498	558	339	489	3,197
May	239	1,007	451	583	364	499	3,143
Jun	217	1,033	383	526	319	485	2,963
Jul	172	915	413	600	334	449	2,883
Aug	203	991	384	533	330	462	2,903
Sep	182	1,006	398	724	302	446	3,058
Oct	149	1,009	451	577	350	474	3,010
Nov	166	989	414	534	303	420	2,826
Dec	260	1,132	380	540	302	458	3,072
Total	2,327	12,084	5,024	6,808	3,938	5,535	35,716
Mean	194	1,007	419	567	328	461	2,976
Percentile	6.5	33.8	14.1	19.1	11.0	15.5	100.0

From the above Tables 1 and 2, the differences in the volume of movements per month per gross tons are very small and the trend is almost identical. These can be further proved in Figure 4 where the graph presented the total number of movements and their sizes in GT. It can be seen that the 100-500 GT predominantly move around the area and followed way behind by the higher grossed vessels. There are also a significant number of vessels of more than 10,000 GT with 16 percent of the total. Vessels less than 100 GT were very few at around 6 % only.

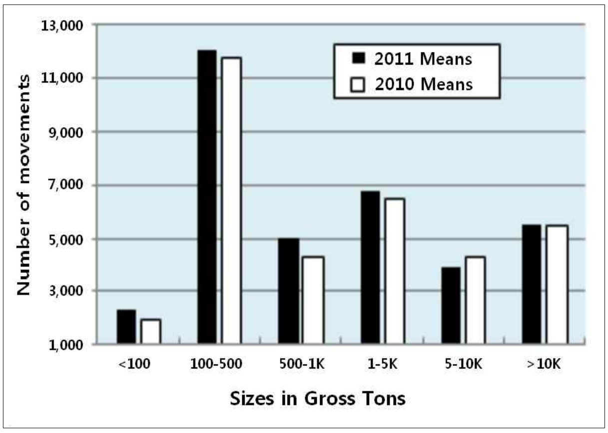

Fig. 4. Volume of traffic per sizes in gross tons[2010-2011].

Compiling the raw data for vessels of more than 100,000 GT, there are outliers recorded averaging once a month movement mostly bound for the oil port of Limao in the province of Bataan across Manila. In 2010, there were 16 movements and the most common visits were from the 150,000 GT vessels with one visit/movement from 199,742 GT in the month of November and one visit from a 223,272 GT vessel in December. In 2011, there were 14 only and the most were from the 160,000 GT vessels followed by 150,000 GT. All vessels were 'foreign' trading and stayed only for about 3 days in port.

2.2.3 According to time of day movement

The Philippines being in the tropics has very little variations in the times of sunrise and sunset, although the civil twilights are longer in the summer months of May to July as calculated from the daily sunrise and sunset times of the Nautical Almanac(2012). Conversely, dusk and dawn times are shorter in the months of November until February. However, the differences are deemed insignificant that the sunrise and sunset are fixed at 0600 and 1800 hours respectively. The volume of vessels' movements per month according to the times of movement is shown in Table 3.

Table 3. Total traffic according to times of day movement (2010-2011)

Time	Day-time		Night-time	
Month \ Year	2010	2011	2010	2011
Jan	1,362	1,537	1,230	1,271
Feb	1,311	1,425	1,203	1,332
Mar	1,252	840	1,430	704
Apr	1,563	1,621	1,336	1,621
May	1,656	1,591	1,437	1,607
Jun	1,460	1,509	1,402	1,498
Jul	1,655	1,416	1,406	1,515
Aug	1,802	1,554	1,490	1,403
Sep	1,598	1,570	1,378	1,314
Oct	1,546	1,674	1,318	1,354
Nov	1,526	1,569	1,383	1,287
Dec	1,607	1,760	1,407	1,404
Total	18,338	18,066	16,420	16,310
Mean	1,528	1,506	1,368	1,359
Percentile	52.76	52.54	47.24	47.43

Night-time traffic for 2010-11 are almost equal while there is a small difference in the 2010-11 daytime movements graphed in Figure 5. This means that there were more traffic during the day than at night, although, a marked decrease in the March movements in 2011 on both times(Table 3).

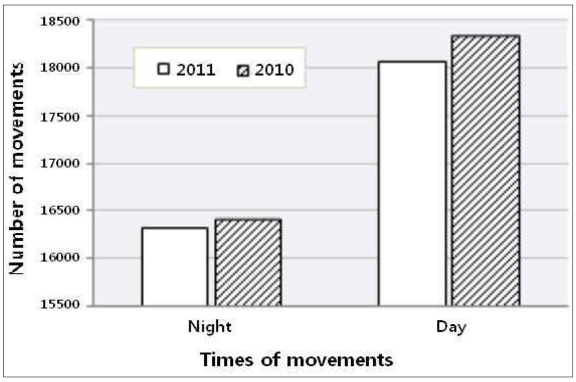

Fig. 5. Volume of traffic according to the times of movement(2010-2011).

The total vessels according to GTs in 2010 shown in Table 1 and the 2011 in Table 2(34,144 and 35,716 respectively), differ from the sums of movements for both years shown in Table 3 which is for vessels according to their times of movements. Inspection of raw data for both years showed that the disparities were caused when some vessels moved more than once during their stay in the port while others showed dates and GTs but no times of movements were recorded. However, the totality of movements were taken into account in this study.

A Pearson product-moment correlation coefficient is used to test the relationship between night and day movements. Tabulated calculation for 2010 shows a 0.60 moderate value and a high 0.79 correlation value for the year 2011. These are shown in Tables 4 and 5.

Table 4. The 2010 computation of Pearson product-moment correlation coefficient between night and day movements

2010＼Mo	Day	Night	Day^2	Night^2	(Day)*(Night)
Jan	1,362	1,230	1,855,044	1,512,900	1,675,260
Feb	1,311	1,203	1,718,721	1,447,209	1,577,133
Mar	1,252	1,430	1,567,504	2,044,900	1,790,360
Apr	1,563	1,336	2,442,969	1,784,896	2,088,168
May	1,656	1,437	2,742,336	2,064,969	2,379,672
Jun	1,460	1,402	2,131,600	1,965,604	2,046,920
Jul	1,655	1,406	2,739,025	1,976,836	2,326,930
Aug	1,802	1,490	3,247,204	2,220,100	2,684,980
Sep	1,598	1,378	2,553,604	1898,884	2,202,044
Oct	1,546	1,318	2,390,116	1,737,124	2,037,628
Nov	1,526	1,383	2,328,676	1,912,689	2,110,458
Dec	1,607	1,407	2,582,449	1,979,649	2,261,049
Total	18,338	16,420	28,299,248	22,545,760	25,180,602

$$r_{xy} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

$$r_{xy} = \frac{1,057,264}{\sqrt{[(3,308,732)^2][(932,720)^2]}}$$

$$r_{xy} = 0.60 \text{ (Moderate correlation)}$$

Table 5. The 2011 computation of relationship between night and day movements using Pearson product-moment correlation coefficient

2010＼Mo	Day	Night	Day^2	Night^2	(Day)*(Night)
Jan	1,537	1,271	2,362,369	1,615,441	1,953,527
Feb	1,425	1,332	2,030,625	1,774,224	1,898,100
Mar	840	704	705,600	495,616	591,360
Apr	1,621	1,621	2,627,641	2,627,641	2,627,641
May	1,591	1,607	2,531,281	2,582,449	2,556,737
Jun	1,509	1,498	2,277,081	2,244,004	2,260,482
Jul	1,416	1,515	2,005,056	2,295,225	2,145,240
Aug	1,554	1,403	2,414,916	1,968,409	2,180,262
Sep	1,570	1,314	2,464,900	1,726,596	2,062,980
Oct	1,674	1,354	2,802,276	1,833,316	2,266,596
Nov	1,569	1,287	2,461,761	1,656,369	2,019,303
Dec	1,760	1,404	3,097,600	1,971,216	2,471,040
Total	18,066	16,310	27,781,106	22,790,506	25,033,268

$$r_{xy} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

$$r_{xy} = \frac{5,742,756}{\sqrt{[(6,992,916)^2][(7,469,972)^2]}}$$

$$r_{xy} = 0.79 \text{ (High relationship)}$$

However, to determine the correlation significance on a one-tailed test for the 2010 traffic using the Spearman coefficient table, the critical tabulated value shows 0.506 at 5 % level of significance and a unacceptable critical result of 0.712 value at 1 % significance level. For 2011, using the same Spearman critical values at 1 % and 5 %, result in both acceptable values at 0.79.

The line graphs of Figure 6(2010) and Figure 7(2011) illustrate the relationship results of the calculations.

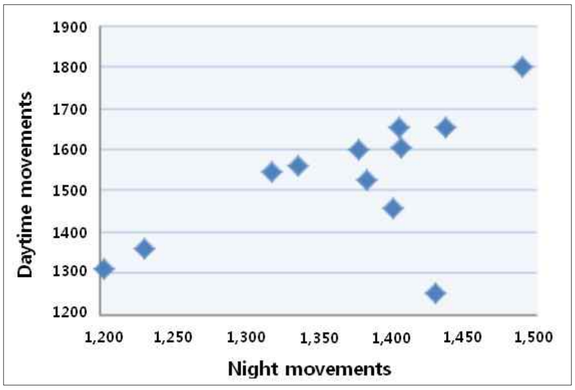

Fig. 6. Line graph of relationship between day(y) and night(x) 2010 traffic with a 0.60 r_{xy} value.

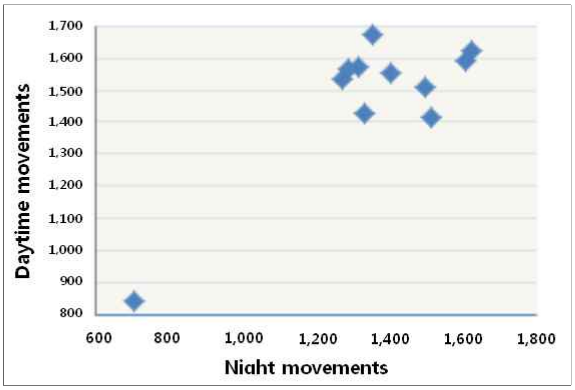

Fig. 7. Line graph relationship between day(y) and night(x) 2011 traffic with a 0.79 r_{xy} value.

To test whether there is any significant difference between night and day in 2010 and 2011, the Chi-square test is used. The following shows the computation in a one-way classification.

$$x^2 = \Sigma \frac{(Obs - Exp)^2}{Expected}$$

	Day	Night	Total
2010	18,338	16,420	34,758
2011	18,066	16,310	34,376
Total	36,404	32,730	69,134

$df_{0.01(1)} = 6.64$

$df_{0.05(1)} = 3.84$

	Obs	Expd	(Obs)-(Exp)	$(Obs\text{-}Exp)^2$	$\frac{(Obs\text{-}Exp)^2}{Exp}$
2010/day	18,338	18,303	35.42	1254.92	0.07
2011/day	18,066	18,101	-35.42	1254.92	0.07
2010/night	16,420	16,455	-35.42	1254.92	0.08
2011/night	16,310	16,275	35.42	1254.92	0.08
Total	69,134	69,134			0.29

The computed value of 0.29 is well below the tabulated values of 6.64 at 1 % level of significance with 1 degree of freedom. At 5 % significance level, the 3.84 value is likewise well above the computed value. This means that there is no significant difference between night and day movements in the two-year data.

The graph in Figure 8 shows that the 100-500 GT vessels, likewise, dominates the moving sea-crafts in the Bay. It is almost identical with Figure 4 “Volume of traffic per sizes in gross tons (2010-2011)” The data collected, however, did not include the types of vessels, hence, further interpretation of their frequency cannot be offered.

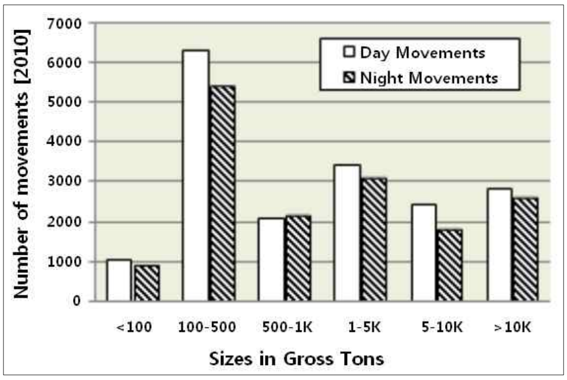

Fig. 8. Sizes of traffic per gross tons during day and night movements.

In the monthly scenario, Figures 9 and 10 illustrate the trend of traffic for the years 2010 and 2011. Figure 9 curves of the 2010 night-time and day-time movements show the rise in traffic from early months where they peaked at the middle months of May and August. The 2011 data shown in Figure 10 is quite steady except in the sudden drop in the month of March. There was also a dive in the curve in this month(March) in the 2010 Figure 9.

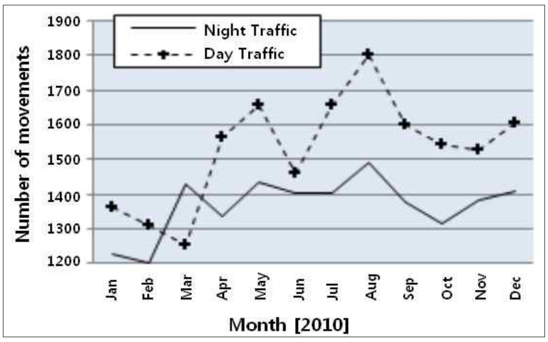

Fig. 9. 2010 traffic volume per day and night.

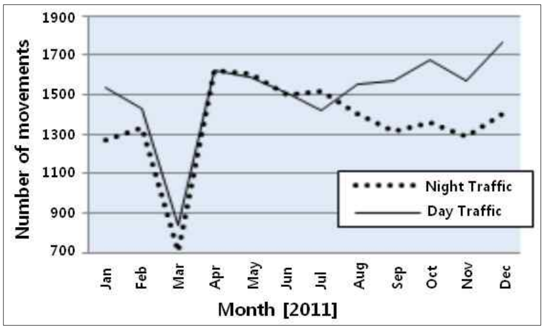

Fig. 10. 2011 traffic volume per day and night.

2.2.4 According to voyage types(Domestic/Foreign)

This section is about traffic movement according to voyage types, domestically or coming from abroad, can be treated similarly. The data compiled in Table 6 are for the years 2010 and 2011 both domestic and foreign trading. It tabulates the summary of traffic in the monthly basis for both years. The monthly data show that they are almost the same for each category.

Table 6. Volume of traffic according to voyage type – domestic and foreign

Voy Type	Domestic		Foreign	
Mo \ Yr	2010	2011	2010	2011
Jan	1,880	2,092	712	716
Feb	1,831	2,103	683	654
Mar	1,997	1,108	685	361
Apr	2,185	2,531	714	720
May	2,325	2,485	768	713
Jun	2,125	2,355	737	652
Jul	2,335	2,270	726	661
Aug	2,557	2,305	735	652
Sep	2,208	2,243	768	641
Oct	2,108	2,347	756	681
Nov	2,219	2,238	690	618
Dec	2,310	2,517	704	647
Total	26,080	26,594	8,678	7,716
Mean	2,866	2,216	723	643
Percentile	75.03	77.34	24.97	22.44
Mean %	76.26		23.74	

In Figure 7, there are large differences between each voyage type and this is somewhat expected because this study focuses on the volume of traffic movements only where the locals is expected to dominate.

The data also show that Manila Bay, being the premier port of the country, home to three harbors, an oil port in Lamao across Manila, and the main fishing Port of Navotas still has minimal foreign shipcalls which may be interpreted by minimal trading internationally. The mean percentile measure shows 76.26 % domestic and only 23.74 % coming from outside the country.

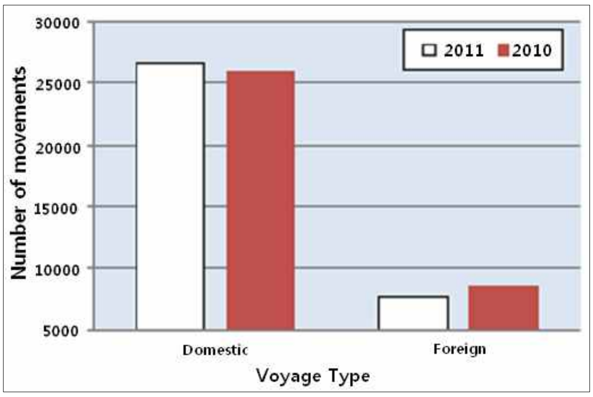

Fig. 7. Volume of traffic per voyage type(2010-2011).

To determine the significant mean difference of the domestic and foreign vessels in 2010 and 2011 traffic, Z-test is applied. To illustrate the hypothesis "Is there any significant mean difference in the domestic and foreign ships traffic movement for 2010 and 2011?", the foregoing is calculated:

2011	Domestic	Foreign
Mean	2216	643
Std Dev.	361.31	90.54

2010	Domestic	Foreign
Mean	2866	723
Std Dev.	491.90	29.13

$$Z = \frac{\tilde{x}_1 - \tilde{x}_2}{SD_1 + SD_2} \qquad Z = \frac{\tilde{x}_1 - \tilde{x}_2}{SD_1 + SD_2}$$

$$Z = \frac{2,216 - 643}{361.31 + 90.54} \qquad Z = \frac{2,866 - 723}{491.9 + 29.13}$$

$$Z = 3.481 \qquad Z = 4.11$$

At 1 % level of confidence, the critical value is 2.58, and the calculated Z-values of 3.481 for 2011 and 4.11 for 2010 are very significant. It menas that the domestic and foreign traffic are significant in both years of study.

Described in Section 2.2.2, there were a total of 30 movements for large vessels at the Port of Limao. All are classified as 'foreign' and only stayed in port for about 3 days. Each recorded movement was only taken once whether arriving or departure. This port, however, is far away from the main port of Manila but still well inside Manila Bay that contributes to the traffic volume of the Bay.

3. Conclusion

This paper has illustrated the pattern and behavior of maritime traffic movement at Manila Bay in the 2-year period. Using the basic statistical methods, it has shown the frequencies between night and day traffic and their significance differences. However, the study cannot make a holistic view of the traffic situation owing to the exclusion of other movements within ports and of wooden outriggers that are not fitted with AIS, the perception of traffic can be used effectively as a basis for further studies in view of improving its safety and competitiveness in harmony to the global demand for higher standards.

To summarize, the following are proved from this study:

a. that the 100-500GT vessels are more frequent movers whether by day or night and at both years(2010 and 2011) throughout the period of survey.

b. that there was no restriction or large difference in the volume of traffic at night or day regardless of size even in the outport of Limao, which is the only frequented port for large vessels of more that 100 K GT.

c. foreign call has been very small compared with the domestic movements. As mentioned earlier, it is as expected but the disparity is very large and most visits were to the outport of Limao.

d. that the relationship between night and day movements is acceptable when using the 5 % significance criterion.

e. that there is no significant difference between night and day movements in the two-year data using the Chi-square method.

f. there is significant mean difference between the foreign and domestic traffic in both years of study.

g. in my future paper, a study of improvement of safety and analysis of risks should be taken priority in line with the findings of this paper.

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