BERTHING PROBLEM OF SHIPS IN CHITTAGONG PORT AND PROPOSAL FOR ITS SOLUTION

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INTRODUCTION

Since 1888, Chittagong port, the main port of Bangladesh with the shore base facilities, has been playing a vital role in the economic development of the country. It has 15 general purpose jetties beside having a few additional jetties to handle oil, clinker, food grain, etc. The jetties were built about nine nautical miles inside from the shoreline of the Bay of Bengal. The ports of the world have changed significantly with the advent of containerization in trade in the seventies of the last century. The port of Chittagong, despite many constraints, continues to cope with the changing patterns of the trade[1]. However, it has been suffering from the problems of poor operational efficiency.

The traffic through the port is increasing along with the economic development of the country. It is frequently seen that a queue of arriving ships is formed and sometimes ships have to wait for a longer time. In addition to that the lack of adequate inland infrastructure to handle containers gives rise to the instances of congestion in jetties and the delays in the final delivery of goods to the importer premises with consequent increase in transportation and other costs.

In this paper, the berthing problem of ships in Chittagong port is analyzed using multi-server queuing models. Data of arrivals and departures of ships from 1994 to 2000 are collected and statistical techniques are applied to find out and analyze the probability distributions and other parameters of the arrival and departure processes. It is predicted that the congestion problem at Chittagong port will take a serious turn after 2015 AD if the present import and export growth rates continue. Therefore, some proposals are made to solve the congestion problem of this important seaport.

JETTY QUEUING MODEL

The system of operation at the port can be thought as a typical queuing process. Ships come to the port as customers to get services and the facilities of the port render services to ships as servers. Here, services refer to handling of cargoes and use of facilities of jetties for berthing of ships. A large portion of the solution of waiting line problems that may arise in practice in Chittagong port involves making decisions in one or a combination of the following:

(a) Number of jetties, needed to serve the arriving ships
(b) Delay of loading/unloading of cargo/container
(c) Future expansion of the facilities

Considering the future expected marine congestion problem at Chittagong port, an attempt is made in the present paper to provide an appropriate guideline to the management of the port authority for the future expansion of berthing facilities.

The problem can be modeled as a multi-server queuing problem with no system limit; arrival can be from a theoretically infinite source. For simplification, only the first come first serve priority rule is applied. Before solving a typical queuing problem, the probability distributions of arrival and service processes are required. Six years' (1994-2000) field data of arrivals and departures of ships to and from Chittagong port is considered. During the period a total of 5726 arrivals took place of which 4832 (84.38% of the total arrivals) are general cargo ships. The year wise breakup of the general cargo ship arrivals is shown in Table 1(a). Table 1(b) shows the actual data of the frequency of ship arrivals and departures.

Chi-square test has been applied to determine the goodness of fit of the actual data shown in Table 1(b) to the standard probability distributions. In an attempt to fit the model to M/M/s(∞), Chi-square test was done for the arrival process considering Poisson distribution. M/M/s(∞) denotes the queuing model for arrival with Poisson distribution and service time with exponential distribution considering infinite server and infinite queuing space. The distribution of arrival of ships is plotted in Fig. 1. It is seen that the arrival process may be fitted nicely with Poisson

Table 1(a): Year wise break-up of ship arrival

Year	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	Grand Total
General Cargo ship	724	718	830	761	900	899	4832

Table 1(b): Frequency of ship arrival and departure

Occurrence of ship arrival in a day	Frequency of the occurrence of arrival	Occurrence of ship departure in a day	Frequency of the occurrence of departure
0	239	0	254
1	529	1	542
2	588	2	557
3	456	3	444
4	218	4	246
5	105	5	100
6	42	6	38
7	13	7	8
8	2	8	3

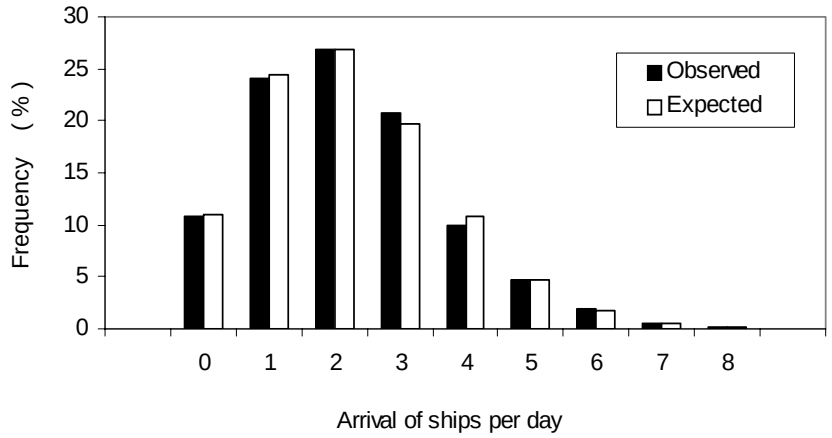

Figure 1: Distributions of arrival of ships per day.

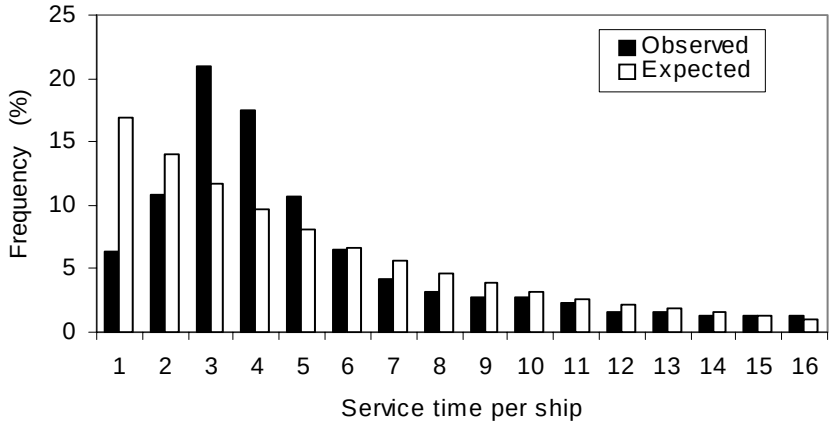

Figure 2: Distributions of service time.

Table 2: Comparison of theoretical results with those obtained by simulation

Parameter	Theoretical model M/M/s (∞)	Simulation
Mean queue length	1.423	1.504
Mean waiting time	0.646	0.688
Mean system time	6.072	6.213
Mean system length	13.370	13.567

distribution. The distribution of service time per ship is plotted in Fig. 2 and it is clear that the service process does not satisfy the assumed exponential distribution in the M/M/s(∞) model. So the berthing problem of the Chittagong port is considered as M/G/s(∞) queuing model. M/G/s(∞), which is same as M/M/s(∞) model except that the service time distribution is non-exponential.

SOLUTION OF THE QUEUING MODEL

Exact solution of the queuing problem is possible only in some limited cases. Simulation and approximation methods are used when exact theoretical solutions are not available. Here Diffusion Approximation method [2-4] has been used to solve the queuing model. At first, a M/M/s (∞) simulation model is developed with the exact data of arrival and departure of ships during the period of 1994-2000 and the results were verified using the exact results available in the textbooks[5] of queuing theory. Since the arrival process fits nicely to Poisson probability distribution, exponential deviates are determined using random numbers generated by computer. Actual data of service time per ship collected between 1994 and 2000 are used to estimate both relative and cumulative frequencies of service times. Using cumulative distribution thus calculated, computer generated random numbers distributed between 0 and 1 and corresponding to each of the service time was selected in the simulation. The calculation and simulation were done for the arrival rate, λ = 2.203 per day, service rate, μ = 5.505 days per ship and number of servers i.e. jetties, S = 15. Mean arrival rate and mean service time used in the model are obtained from the actual collected data. Table 2 shows the results obtained from the M/M/s(∞) model and simulation. The mean system length was also varied by Diffusion Approximation method in which diffusion equations are solved using MathCAD 2000 professional software and system length, L_s was found to be equal to 13.404. This validates the developed simulation program. This simulation was later applied to solve M/G/s(∞) queue model which represents the berthing problem of the Chittagong port.

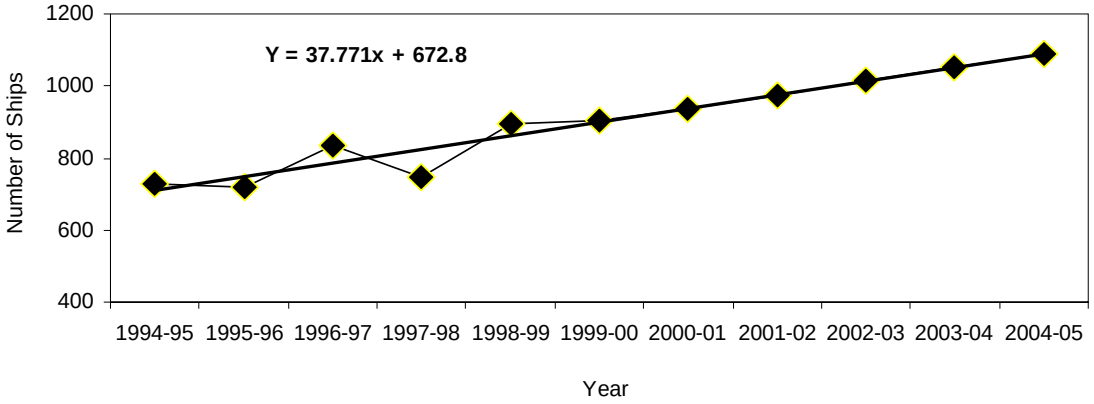

Figure 3: Forecast of arrival of ships at Chittagong port.

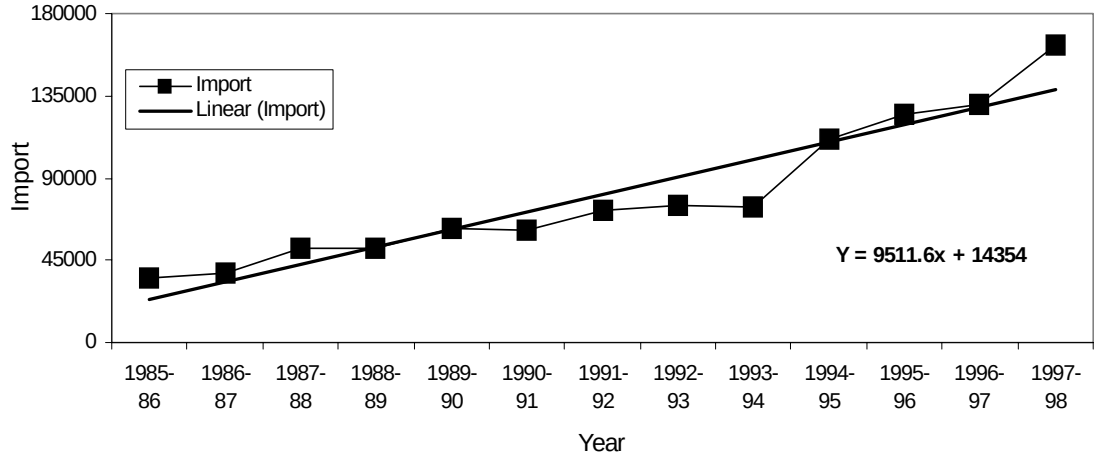

Figure 4: Forecast of import

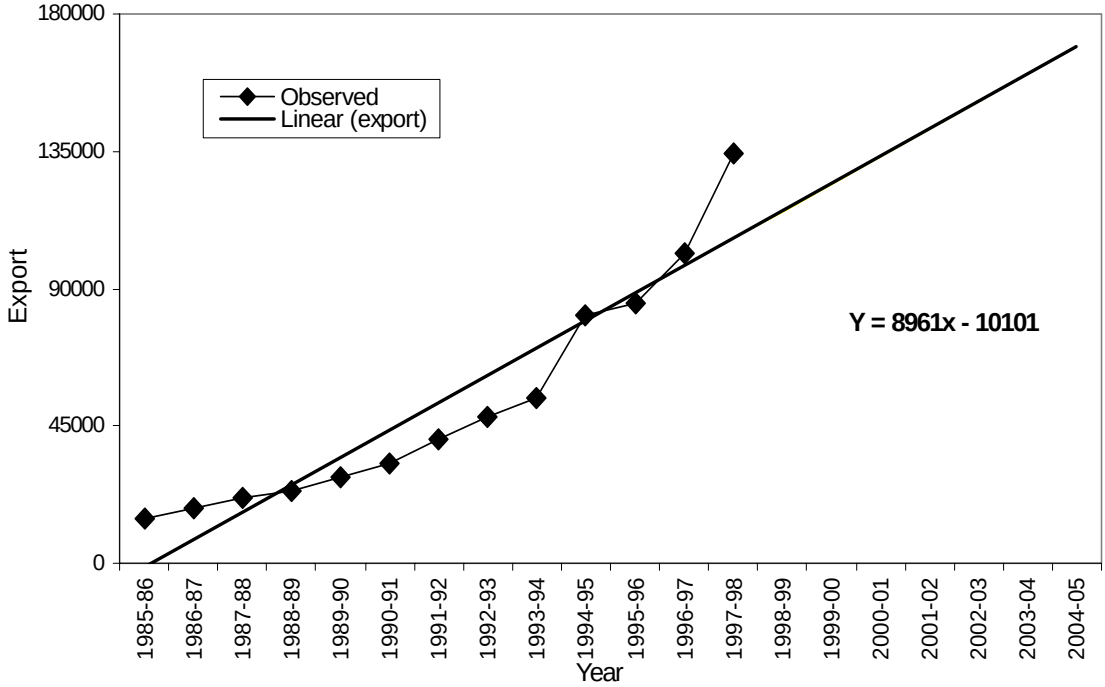

Figure 5: Forecast of export.

Table 3: Forecast of imports

Year	Imports	Arrival of ships
2005	204594	998
2010	252154	1131
2015	299714	1264
2020	347274	1398
2025	394834	1531
2030	442394	1664

Table 4: Forecast of exports

Year	Exports	Arrival of ships
2005	169119	973
2010	213924	1090
2015	258729	1206
2020	303534	1323
2025	348339	1439
2030	393144	1556

Table 5: Forecasted arrival rates

Year	Average arrival ships	% increase of arrival	Arrival rate
2005	986	1.08	2.38
2010	1110	1.22	2.68
2015	1235	1.36	2.99
2020	1361	1.50	3.30
2025	1485	1.64	3.61
2030	1610	1.77	3.89

Table 6: Forecasted variations of system parameters

Year	No of jetties	Mean queue length	Mean waiting time
2005	15	14.44	6.13
	16	3.80	1.60
2010	17	12.05	4.54
	18	4.25	1.60
2015	18	107.24	36.17
	19	12.82	4.32
	20	4.63	1.56
2020	20	78.59	24.04
	21	9.31	2.84
2025	22	43.02	11.99
	23	9.86	2.77
2030	24	23.45	6.05
	25	10.15	2.62

FORECASTING OF ARRIVAL OF SHIPS

Arrival of ships to a port is dependent on imports and exports, population growth, economic condition etc. Imports to and export from a country may take place through sea, land and air. In this study, for simplicity, it is assumed that all exports and imports of Bangladesh take place through the two seaports at Chittagong and Mongla and that Chittagong port handles 60 % of total import and export. Import and export data[6] of the period 1985~98 are used to forecast the expected import and export up to the year of 2030. At the same time, forecast for expected arrival of ships during the same period in future was made using six years' actual data of Table 1(b). These data are graphically plotted in Figs. 3-5. The equations of the trend lines based on the Linear Regression of the actual data are shown in the respective plot. In these plots Y denotes either the number of arrival of ships or the import/ export value in million Taka and x is year. The correlations between the arrival of ships and import and the arrival of ships and export are calculated. The coefficient of correlation in the case of import is 0.64 and in the case of export is 0.63. Due to the simplified assumptions, coefficient of correlations has become considerably low. The forecasted values would have been more accurate had they been above 80 %. Then based on the forecasted imports and exports, arrival of ships up to 2030 AD have been forecasted and the results are shown in Tables 3 and 4. Finally, the expected arrival rate of ships for the next 30 year is calculated and shown in Table 5. Here, average arrival of ships is the average value of the forecasted arrivals due to both import and export as listed in Tables 3 and 4. % increase shown in Table 5 is based on the forecasted arrivals of ship in the year 2000 which is 905. Expected arrival rate is calculated considering average arrival rate for the years 94 -95 to 99 - 2000, which is 2.203 ships per day.

Simulation is done using present service condition i.e. using actual service time for the years 1994 to 2000 and inter-arrival time generated by using forecasted arrival rate considering inter-arrival time that follows exponential distribution. Number of jetties was considered 15 and the queue parameters were calculated considering the current service pattern. Later keeping other conditions same number of jetties is increased to bring down the average waiting time to almost equal to that of present or acceptable limit. The results are shown in Table 6. It is seen that by 2030, extra 12 to13 jetties will have to be added in phases with related backup facilities.

OBSERVATION

Although in doing simulation present state of service pattern is used, due to containerization service will be faster. A recent study by Sanjib and Biswas[7] has shown that service is being delayed in container handling because of improper utilization of handling equipment. If faster service is provided by optimum utilization of container handling equipment, corresponding queue length and waiting in queue will decrease further. On the other hand, due to probable increase in growth of economy, trade, globalization etc. arrival of ships might also increase. It is estimated that until 2030 if additional 12~13 jetties are constructed and related backup facilities e.g., container yard, handling equipment etc. are provided, there would not be any serious problem. After 2030 new sites must be explored and Kutubdia channel might be a good site. Some proposals for the expansion scheme are listed below for the immediate consideration of the Chittagong Port Authority:

Possibility of expansion at present site: Three sites can be considered for possible expansion. These are in New Mooring, Near khal no. 15 to Naval Academy and between jetty no. 1 and slip way dock.

(1) Expansion in New Mooring: Temporary jetties (No. 14~17) in New Mooring constructed in 1960 under short-term plan is no longer functional. The Chittagong Port Authority may reconstruct the jetties in front of the container terminal project in New Mooring area.

(2) Near Khal No. 15 to Naval Academy: Presently, there is no space on the right bank of the river Karnaphully for the expansion of jetties from BNS Isha Khan to Chittagong Dry Dock Ltd. After that point, there are two ferry ghats, one for customs and the other for Marine Academy. After the Marine Academy ghat, though the riverside is free, jetty construction is not possible in this location due to Air port traffic. Therefore, from Khal no. 15 to Naval Academy can only be utilized for jetty

construction, for handling container. A cost analysis was done for the construction in this site and it is found that benefit cost ratio is 1.24 which supports the viability of expansion. In the Master Plan and Trade Facilitation Study–Draft Report[8,9], it was shown that there is sufficient water-front available on the right bank of the Karnaphully to accommodate the container handling capacity which needs to be developed over the next twenty years to meet the projected container traffic growth.

(3) Between jetty no. 1 and slipway dock: In front of slipway dock, there is silt deposition, and also draft is very low during high tide. So, for the construction of jetty, dredging is required in this location, so that 10.0 meter draught vessel can be allowed for berthing.

Possibility of expansion at other sites: The Possible sites are Kutubdia channel and the left bank of the Karnaphully i.e., beside KAFCO (Karnaphully Fertilizer Company). Bangladesh Port System Management Development Project: Master Plan assessed the feasibility of constructing an impound dock on the left bank of the river Karnaphully, just downstream of the KAFCO marine terminal. The dock is intended to enable Chittagong Port to expand its container handling capacity in future.

The use of the impound dock (Basins) is normally reserved for ports where extreme tidal ranges make it impractical to carry out ship to shore cargo operations. Construction of impounded dock was more common in the past when ships were smaller and cargo-handling methods were not that advanced. Today new impounded docks are rare and more of these facilities are being abandoned. Still many remaining in useful service where tidal conditions or port congestion problem are severe. Chittagong Port Authority is already constructing new jetties and back-up facilities. These jetties will be less expensive than the proposed impounded dock and jetties in Kutubdia channel, as access road and rail connection already exist there.

After that if expansion of jetties is further required it will be better to construct jetty in the vacant space in the right bank of the Karnaphully, between Khal no. 15 to Naval Academy. Because access road will not be required to construct, only few kilo meters of rail road will be required to be extended.

Due to globalization, Bangladesh Govermentt. might allow Nepal, Bhutan and the Eastern states of India to use Chittagong port. In this situation, Kutubdia channel may be taken into consideration to construct jetty which will be better and less expensive than proposed impounded dock in the left bank of the Karnaphully. Moreover, construction of deep seaport may also be given due consideration.

CONCLUSION

No major expansion of berthing facilities of the port of Chittagong has been made since 1960. Though two multi-purpose berths were built in 1998, they are not sufficient for high berth occupancy. Forecast result shows projected growth of traffic i.e., arrival of ships will increase 1.22 times in the next ten years and 1.77 times in the next 30 years.

Since trade is increasing and present berthing (jetty) facilities are not sufficient, serious congestion problem will occur in the near future i.e., around 2020. If queue becomes very large either the ships will have to wait for a long time or to leave Chittagong port. Present data and the forecasted results indicate that the expansion is necessary. So, alternative suggestions which have been made may be given due consideration.

Simulation results show if New Mooring container jetties and one jetty near jetty no. 1 are constructed the problem will not be acute in the next 5~7 years. After that, construction of new 5 jetties near khal no. 15 is needed to handle cargo until about 2030. If no new construction of berths is made the problem will be acute within about 10 years.

It can be shown by economic analysis that extra involvement for construction of jetty and backup facilities will be balanced by extra benefit within a span of 10 to 15 years. In the analysis no priority, no balking, no reneging have been considered. If facilities are provided balking and reneging might also happen in future.

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