Optimising the Deployment of Shiploader Using Simulation

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Abstract Bulk commodity export terminals are equipped with very expensive infrastructure. The massive capital outlay is also accompanied by large operating costs associated with major equipments such as shiploaders, reclaimers, unloading stations, etc. The port management is always interested in optimising the deployment of its infrastructure with a view to minimising the terminal's operating costs. This study deals with finding an optimal solution to an interesting situation where using one shiploader results in unacceptable ship waiting times and high level of demurrage while continuous deployment of two shiploaders results in inefficiency and high operating costs. The paper describes an approach for developing a strategy which considers trade-off between ship waiting cost and the cost of deploying the additional shiploader resulting in optimal deployment of resources. The approach is an integration of simulation, scenario building, and economic fundamentals. An actual bulk export terminal in Australia is used to demonstrate the applicability of this approach in assisting the port management in rational decision-making.

1. INTRODUCTION

1.1 Outloading Infrastructure

The bulk export terminal under consideration has four rows of stockpiles. It has six reclaimers and two outloading strings each with its own surge bins. There are two shiploaders. Infact, there are two parallel outloading systems each with a rated capacity of 7,200 tonnes per hour (tph). The outloading system at the terminal is represented schematically in Figure 1.

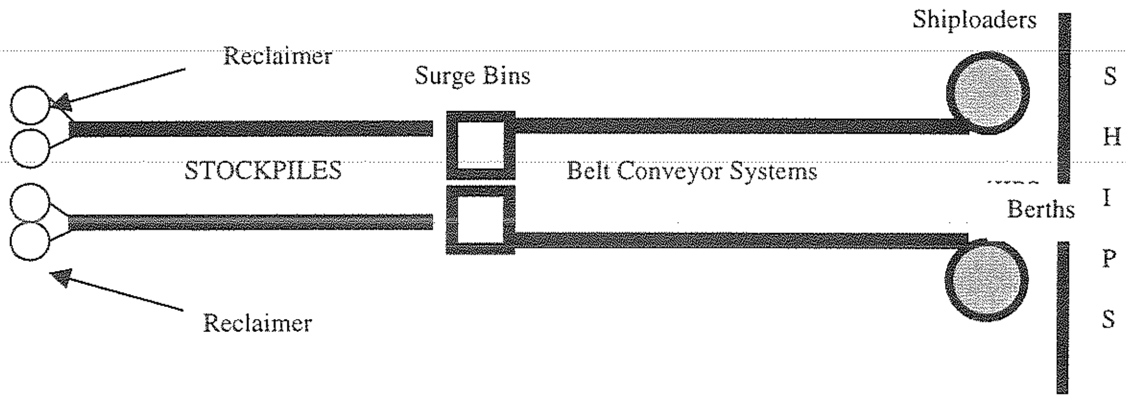

Figure 1: The Outloading System

1.2 Operational Procedure

When a ship is to be loaded, two reclaimers, if available, reclaim the commodity from designated stockpiles. It is loaded by a shiploader through an outloading system consisting of a surge bin and several kilometers of belt conveyor. A ship is loaded with one shiploader only although each shiploader can work on either of the two berths.

Only the newer shiploader (SL2) is deployed for loading ships irrespective of the berth at which the ship is to be loaded. The shiploaders are not dedicated and can travel to either berth. It is the policy of the management of the terminal not to use both shiploaders for loading a single ship. Only very few ships (Capesize carriers loading a single product) may be able to accept two loaders simultaneously for a limited period of time. This option is not considered in this study.

1.3 Problem Definition

At the rated capacity of 7,200 tph, one shiploader can practically handle a throughput of over 30 MTPA with acceptable performance levels. Two shiploaders will be gainfully deployed when the throughput is in excess of 42 MTPA. However, at the present and in the near future time frame, the throughput is expected to range around 30 – 35 MTPA. This means that the continuous deployment of two shiploaders is not fully justified in economic terms.

Shiploader SL2 is deployed for the loading of all ships and SL1 is assigned only while SL2 is under maintenance. This means that one shiploader is always available with crew assigned. This policy is based on the conviction that the cost of continually manning two shiploaders could be prohibitive. This may not, however, be an optimal practice as queues may form, waiting time and turnaround time of ships may increase, and demurrage may be too high. To relieve congested situations, SL1 may have to be deployed selectively.

1.4 Objectives and Approach

The approach to the development of an optimal operational regime is to simulate alternative shiploader deployment strategies. The objective is to recommend a desirable strategy which will offset the additional costs of operating the second shiploader by reducing demurrage. This is achieved by simulating the performance of the outloading operations by using the port simulation model developed at James Cook University for the export terminal.

2. THE SIMULATION ENVIRONMENT

2.1 The Simulation Model

The integrated front- and back-of-port model developed for the export terminal by the School of Engineering at James Cook University has been deployed in this study. The model is programmed in a special-purpose language – ARENA. An earlier version of this model was used to evaluate alternative strategies for planning the operations of this terminal (Wadhwa 1992).

Model inputs relating to the proportion of users' tonnages, the ship generation stream, the durations and frequency of port closures, maintenance regimes for the outloading strings and berths, etc. are provided by the management of the terminal. The proportion of ships carrying blended cargo has been ascertained from the available data, for each ship category.

2.2 Formulating Strategies

It is hypothesised that the deployment of the second shiploader should be triggered by the state of the system. In any systems study, an action is initiated when the system state reaches a certain threshold or critical level. In this study, the state which should logically trigger the deployment of the second shiploader is the anchorage queue length.

Although this approach to formulating alternative strategies can lead to a continuum of possible deployment strategies, the following five strategies are selected for simulation and analysis (Table 1). The deployment of the second shiploader ceases as soon as the condition which resulted in its deployment no longer exists.

Table 1: Anchorage Queue for Deployment of SL1

Strategy	Anchorage Queue	Remarks
A	0	as soon as the second ship berths
B	1	two ships berthed, one in queue
C	2	two ships berthed, two in queue
D	3	two ships berthed, three in queue
E	infinite	SL1 not deployed (except when SL2 is under maintenance)

2.3 Shiploader Maintenance Schedule

The maintenance schedule for SL2 is as follows:
12 hours every 1 million tonne
36 hours every 4 million tonnes, and
132 hours every 8 million tonnes

Since SL1 is not deployed continuously, its maintenance is not modelled. It is presumed that maintenance on SL1 will be carried out during its non-allocated period and will, therefore, always be available for deployment, when required.

2.4 Range of Throughput Simulated

Throughputs from 28 MTPA (million tonnes per annum) to 33 MTPA, in increment of about one MTPA have been simulated for each strategy.

2.5 Despatch/Demurrage

One of the most relevant measure of terminal's operational performance is despatch/ demurrage. This economic indicator is a function of the time spent by the ship in the port. If a ship's turnaround time is less than an agreed time derived rationally by an established formula, the terminal is credited with "despatch"; however, if the ship's time in port exceeds the agreed time, the terminal incurs "demurrage". The rate of demurrage is twice the rate of despatch.

3. SIMULATION OF DEPLOYMENT STRATEGIES

The key statistics which have been considered in evaluating alternative strategies include

- Demurrage
- Frequency of deployment of second shiploader
- Total number of hours for which second shiploader has to be deployed in a year

3.1.1 Strategy A: Deploy second shiploader as soon as the second ship is berthed.

This strategy requires frequent deployment of the second shiploader. This is shown in Table 2. However, the despatch is maximum for this strategy. The relatively high despatch is achieved at the cost of the significant expenditure in deploying second shiploader. In this strategy, despatch decreases from a maximum of 6.68¢ at 28 MTPA to just 1.34¢ at 33 MTPA. The number of times for which the second shiploader had to be deployed is shown to vary from 110 to 161. The second shiploader is used for 1,648 hrs in case of 28MTPA increasing to 2,442 hrs for 33 MTPA.

Table 2: Summary of Results for Strategy A

Throu-put (MTPA)	Freq. of deploy. (no./yr)	Hours deployed (hrs. / yr)	Despatch/ demurrage (US¢/tonne)
28.28	110	1648	6.68
29.23	123	1828	6.27
30.60	135	2038	5.30
31.98	144	2155	4.07
33.22	161	2442	1.34

3.1.2 Strategy B: Deploy second shiploader when two ships are berthed and another ship enters the queue

This strategy also requires frequent deployment of second shiploader. The number of times and the hours for which the second shiploader is used are quite substantial. The despatch is still high but lower than for strategy A as shown in Table 3.

Table 3: Summary of Results for Strategy B

Through-put (MTPA)	Freq. of deploy. (no. / yr)	Hours deployed (hrs. / yr)	Despatch/ demurrage (US¢/ tonne)
28.21	55	887	6.83
29.27	68	998	5.81
30.52	79	1170	5.15
31.50	83	1228	4.05
32.82	97	1450	2.86
33.53	105	1582	1.78

In this strategy, the despatch decreases from a maximum of 6.83¢ at 28 MTPA to a minimum of 1.78¢ per tonne at 33 MTPA. The number of times for which the second shiploader has to be deployed is shown to vary from 55 to 105. The second shiploader is used for 887 hrs for 28 MTPA increasing to 1582 hrs for 33 MTPA.

3.1.3 Strategy C: Deploy second shiploader when two ships are berthed and a second ship joins the anchorage queue.

As shown in Table 4, despatch decreases from 5.70¢/tonne at 28 MTPA to a slight demurrage of 0.2¢ at 33 MTPA. The number of times for which the second shiploader has to be deployed is shown to vary from 32 to 59. The second shiploader is used for 468 hrs for 28 MTPA increasing to 914 hrs for a throughput of 33 MTPA.

Table 4: Summary of Results for Strategy C

Through put (MTPA)	Freq. of deploy. (no./yr)	Hours deployed (hrs. / yr)	Despatch/ demurrage (US¢/tonne)
28.21	32	468	5.70
29.68	42	671	4.75
30.60	44	657	4.86
31.77	44	766	4.55
32.59	51	737	2.65
33.20	59	914	-0.12

3.1.4 Strategy D: Deploy second shiploader when two ships are berthed and the anchorage queue increases to three.

The results of simulating this strategy (Table 5) show that despatch decreases from a maximum of 3.62¢/tonne at 28 MTPA to a demurrage of 3.51¢/tonne at 33 MTPA. The number of times for which the second shiploader has to be deployed is shown to vary from 13 to 48. The second shiploader is used for 163 hrs for 28 MTPA increasing to 739 hrs for a throughput of 33 MTPA.

Table 5: Summary of Results for Strategy D

Through put (MTPA)	Freq. of deploy. (no./ yr)	Hours deployed (hrs./ yr)	Despatch/ demurrage (US¢/ tonne)
28.03	13	163	3.62
29.09	16	256	3.65
30.09	27	364	1.46
31.05	28	476	0.13
31.99	34	398	-0.62
33.09	48	739	-3.51

3.1.5 Strategy E: Deploy second shiploader only when SL2 is under maintenance.

This strategy requires minimal deployment of second shiploader. However, the demurrage is maximum under this strategy. The high demurrage is a trade-off due to limited deployment of second shiploader. A despatch of 1¢/tonne at 28 MTPA rapidly drops to a demurrage of about 52¢/tonne at 33.4 MTPA. The frequency and duration of deployment of SL1 under this strategy is only dependent on the maintenance schedule of SL2. This is shown in Table 6.

The results of various simulations are displayed in Figure 2.

Table 6: Summary of Results for Strategy E

Throughput (MTPA)	Despatch/demurrage (US ¢ / tonne)
28.03	1.06
29.13	-1.28
30.06	-5.45
31.00	-10.90
32.01	-19.54
32.90	-35.11
33.37	-51.72

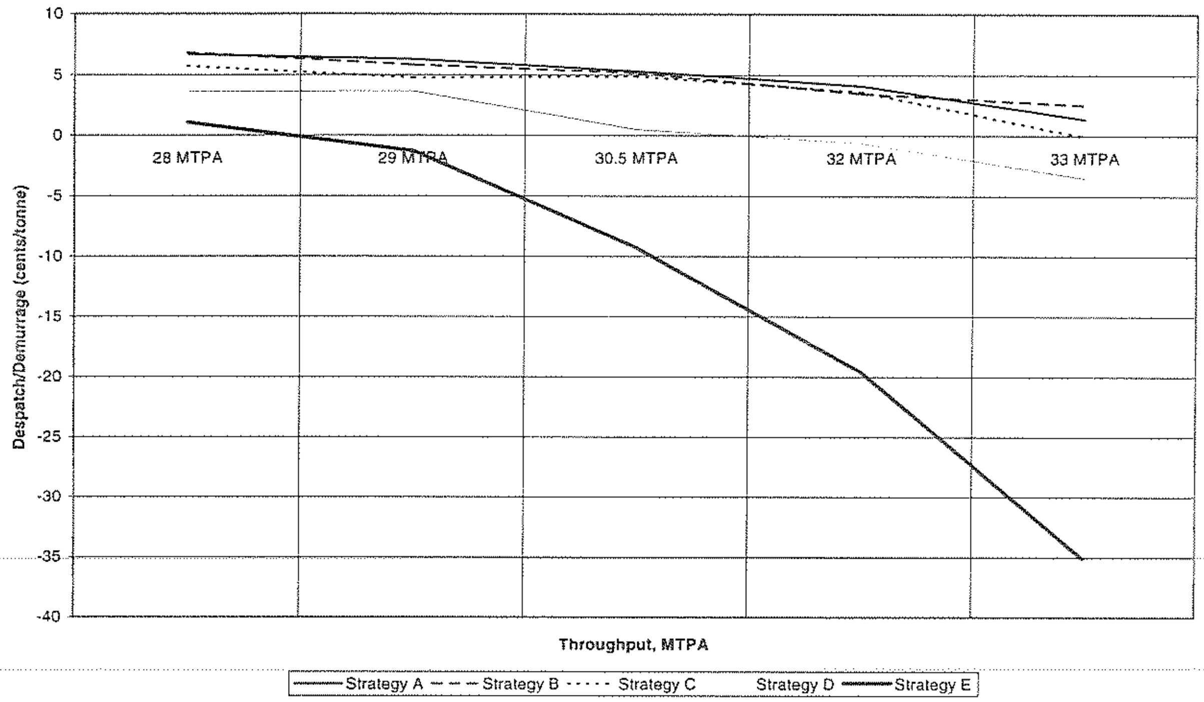

Figure 2: Effect of Different Deployment Strategies at Varying Throughput

4. INTERPRETATION OF SIMULATION RESULTS

Some obvious results from the simulation of alternative strategies are that

- in moving from strategy A to E, the deployment of second shiploader reduces in frequency and total duration of deployment
- as the deployment of second shiploader decreases, the despatch decreases and demurrage levels increase
- for the same strategy, demurrage increases as throughput increases.

However, an in-depth perusal of simulation results (5 strategies and throughput levels ranging from 28 MTPA to 33 MTPA) is required to fully appreciate the trade-offs involved and make a rational and logical recommendation.

4.1 Despatch/Demurrage

The effect of adopting alternative strategies on despatch/demurrage has been examined for various levels of throughput. The effect of increasing throughput on despatch / demurrage is shown for each strategy in Figure 2. The figure clearly shows the merits of strategies A, B, and C at all throughput levels. It is obvious that as throughput increases, the strategy of deploying second shiploader with a queue of one or two ships becomes more attractive. The strategy of deploying SL1 only in case of the maintenance of SL2 (strategy E) results in significant demurrage at higher throughput.

4.2 Frequency of Deployment of Second Shiploader

There is a rapid fall in the frequency of deployment in going from strategy A to B but the rate of decline reduces when shifting from strategy B to C and further on to D. There is a moderate increase in the frequency of deployment with increase in throughput for any strategy. It is obvious from Tables 2 to 6 that the frequency of deployment for any strategy increases with increase in throughput. As the strategy shifts towards deploying second shiploader with longer queues, the frequency of deployment decreases.

4.3 Proportion of Ships Serviced by Second Shiploader

As throughput increases, the number of ships unloaded also increases. It is instructive to examine if the proportion of ships which are serviced by the second shiploader for each strategy also increases with the level of throughput. This proportion has been determined for all throughput levels and strategies and follws similar pattern to the frequency of deployment.

4.4 Total Duration of Deployment of Second Shiploader

The duration of deployment is expressed in terms of number of hours for which the second shiploader is expected to be deployed under any strategy. The simulation results reinforce the pattern of variations in duration of deployment with increasing throughput and for various strategies similar to the effect on the frequency of deployment.

4.5 Average Deployment Duration

The average number of hours for which the second shiploader is deployed is remarkably similar for all throughputs and all strategies. This figure has been found to be around 15±2 hours for each deployment. There is no pattern to suggest a systematic effect due either to the throughput or the strategy on the average duration of deployment of the second shiploader.

5. DISCUSSION AND CONCLUSIONS

Realising that the current throughput level at the terminal does not warrant the continuous deployment of two shiploaders, it has been premised that

- the new shiploader (SL2) be used as the primary loading facility,

- hours per annum while the despatch also reduces by about 5 to 7 cents per tonne for the range of strategies considered.

- the previous shiploader (SL1) be deployed whenever SL2 is under maintenance.

- based on an appropriate strategy triggered by the system state, both SL1 and SL2 be deployed to load two ships simultaneously

Four alternative deployment strategies have been formulated in addition to the strategy of not deploying the second shiploader except during maintenance of SL2 (Strategy E). These are:

- Deploy SL1 as soon as the second ship is berthed (strategy A)

- Deploy SL1 as soon as the third ship arrives in the system, i.e. two ships are berthed and the third has to join the queue – only one ship in the queue (strategy B)

- Deploy SL1 as soon as the fourth ship arrives in the system, i.e. two ships are berthed, there is one ship already in the queue and the new ship joins the queue whose length becomes 2 ships (strategy C)

- Deploy SL1 as soon as the fifth ship arrives in the system, i.e. two ships are berthed, there are two ships already in the queue and the new ship joins the queue whose length becomes 3 ships (strategy D)

These strategies have been simulated using throughput levels between 28 MTPA to 33 MTPA. Some significant results of this study include the following:

- The rate of reduction in the frequency of deployment of second shiploader decreases as we move towards the strategies of deployment with longer queue length.

- The proportion of ships serviced by the second shiploader increases with increase in throughput and decreases with the move from strategy A to strategy D. This pattern is similar to the frequency of deployment variations.

- The average number of hours for which the second shiploader is deployed for each deployment is remarkably similar across all throughput levels and strategies. The average value is 15±2 hours for each deployment.

- As the throughput increases from 28 MTPA to 33 MTPA, the number of hours of deployment of second shiploader increases by 500 to 800

- Increasing the hours of deployment by switching strategies brings much higher returns

(0.30 cents/tonne increase in despatch for every 100 additional hours of deployment per year) at throughput levels of 30 MTPA or higher compared to a benefit of under 0.20 cents/tonne at throughputs below 30 MTPA. (The effectiveness of deployment is measured by the elasticity of deployment which has been defined as the increase in despatch per 100 hours of additional deployment of second shiploader)

It is recommended that second shiploader need not be deployed except during maintenance of SL2 (Strategy E) at a throughput of 28 MTPA. This policy is, however, uneconomical for throughputs exceeding 30 MTPA. The benefits of deploying the second shiploader are greater at higher throughputs and a strategy of deploying the second shiploader when the second ship joins the anchorage queue while both berths are occupied (strategy C) is quite appropriate.

6. ACKNOWLEDGEMENTS

The continuing help of Mr. Manfred Schneider in the development of this study, discussion of the methodology, and critical assessment of preliminary results is highly appreciated. Mr. Dominique Morel carried out the simulations while working in the United Kingdom.

7. REFERENCES

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