OPTIMUM ALLOCATION OF BERTHS TO BAYS

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ABSTRACT

Maritime container terminals are facilities where cargo containers are trans shipped between ships or between ships and land vehicles (trucks or trains). These terminals involve a large number of complex and combinatorial problems. The problem of berth allocation is such a problem. The terminal operator normally demands all containers bound for an incoming vessel to be ready in the terminal before its arrival. Similarly, customers (i.e., vessel owners) expect prompt berthing of their vessels upon arrival.

In this paper, assignment model is used for optimizing the berth allocation problem. The algorithm for solving the berth allocation problem generates an optimized order of vessels to be served. This technique will minimize disruptions and facilitate planning in container terminals.

KEY WORDS: Berth allocation, Assignment Model, transportation time.

1. INTRODUCTION

Container terminals have become an important component of global logistics networks. Container terminals have become an important component of global logistics networks.

The operations of the port are very complex. The loading operation of the containers on the ships is as follows. The containers are stored in the container yard. The containers are loaded on special trucks or straddle carriers by cranes and brought to the quay. Here they are loaded on the crafts or onto ships directly by cranes. The transport rate of the containers depends on the capacity and the transport rate of both the ships and the straddle carrier. The maximum capacity of crane is to handle 30 containers per hour. This handling capacity cannot be achieved at all times because of breakdown of cranes and/or straddle carriers. However, a fairly realistic rate of 18 containers per hour can be considered as good actual rate. The operation is reversed when the containers are removed from the ship.

Containers are metal boxes and can be stacked on top of each other. The container capacity is often expressed in twenty-foot equivalent unit (TEU). Loading and offloading containers on the stack is performed by cranes following a 'last in, first-out' (LIFO) storage.

In order to access a container which is not at the top of its pile, those above it must be relocated. It occurs since other ships have been unloaded later or containers have been stacked in the wrong order due
to lack of accurate information. Contain relocation reduces the productivity of the cranes. Maximizing the efficiency of this process leads to several requirements:

1. Each incoming container should be allocated a place in the stack which should be free and supported at the time of arrival.

2. Each outgoing container should be easily accessible, and preferably close to its unloading position, at the time of its departure.

Generally this problem can be seen in two different approaches according to when it should be optimized:

1. Minimizing the number of relocations during the pickup operation.

2. Getting a desirable layout for the bay before the pickup operation is done in order to minimize (or eliminate) the number of relocations during this process.

This paper presents an assignment model that is used to reduce the total distance travelled.

2. LITERATURE SURVEY

Murtya\textsuperscript{(2)} has developed a container support system for berth allocation for port optimization for the port of Hong Kong. It describes the work being carried out to develop a decision support system (DSS; computerized decision support system). As reported in “Integrated intelligent techniques for remarshaling and berthing in maritime terminals” \textsuperscript{(3)} two algorithms are developed for berthing allocation. The theory from “A survey of berth allocation and quay crane scheduling problems in container terminals” \textsuperscript{(4)} gives the impact of berthing positions on the handling times on BAP formulations. The interdependencies between the quay crane resource utilization and the vessel handling times has also been highlighted. Another important issue for the success at any container terminal is to forecast container throughput accurately. \textsuperscript{(5)}

3. METHODOLOGY

3.1 Data Collection

The data has been collected for a port that has 5 bays and 8 berths for loading the containers and 8 berths for unloading the containers.

The data collected is for the distance between the bays and the location for loading and unloading on the port.
Table 1: Distance between loading location and berths

<table>
<thead>
<tr>
<th>Locations for Loading</th>
<th>Berths 1</th>
<th>Berths 2</th>
<th>Berths 3</th>
<th>Berths 4</th>
<th>Berths 5</th>
<th>Berths 6</th>
<th>Berths 7</th>
<th>Berths 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>350</td>
<td>380</td>
<td>410</td>
<td>435</td>
<td>480</td>
<td>500</td>
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<td>1000</td>
<td>1015</td>
<td>1030</td>
</tr>
</tbody>
</table>

All distances are in meters.

Table 2: Distance between unloading location and berths

<table>
<thead>
<tr>
<th>Locations for unloading</th>
<th>Berths 1</th>
<th>Berths 2</th>
<th>Berths 3</th>
<th>Berths 4</th>
<th>Berths 5</th>
<th>Berths 6</th>
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<td>1150</td>
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<td>1185</td>
</tr>
</tbody>
</table>

3.2 Method

The assignment problem is one of the fundamental combinatorial optimization problems in the branch of optimization or operations research in mathematics. It consists of finding a maximum weight matching in a weighted bipartite graph. Assignment model is used to solve the problem.

Assignment problems involve optimally matching the elements of two or more sets, where the dimension of the problem refers to the number of sets of elements to be matched. When there are only two sets, as will be the case for most of the variations we will consider, they may be referred to as "tasks" and "agents". Thus, for example, "tasks" may be jobs to be done and "agents" the people or machines that can do them. In its original version, the assignment problem involved assigning each task to a different agent, with each agent being assigned at most one task (a one-to-one assignment). While only two of the models to be discussed involve assigning multiple agents to a task, some of the models do assign multiple tasks to the same agent (a one-to-many assignments). The models to be discussed first, however, assign no more than one task to any given agent. (6)
3.3 Analysis

Table 3 : Distance matrix. Initial Table

<table>
<thead>
<tr>
<th>Berths</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</tr>
</thead>
<tbody>
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<td>350</td>
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<td>970</td>
<td>985</td>
<td>1000</td>
<td>1015</td>
<td>1030</td>
</tr>
</tbody>
</table>

To solve assignment model, we need a square matrix and the current format has degeneracy so we add 3 dummy rows so as to make number of rows equal to the number of columns. The problem is hence converted into an assignment problem and solved by Hungarian method.

Table 4 : Formulation of Assignment Model

<table>
<thead>
<tr>
<th>Berths</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
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</tr>
</tbody>
</table>

Table 5 : Final solution

<table>
<thead>
<tr>
<th>Berths</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<td>35</td>
<td>55</td>
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<td>45</td>
</tr>
<tr>
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<td>30</td>
<td>15</td>
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<tr>
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<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
So the allocations are as follows:

Bay 1 is assigned to berth 1, Bay 2 is assigned to berth 2, Bay 3 is assigned to berth 4, Bay 4 is assigned to berth 3 and Bay 5 is assigned to berth 5.

**Final Allocation**

<table>
<thead>
<tr>
<th>Bay</th>
<th>Berth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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<tr>
<td>3</td>
<td>4</td>
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<tr>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Therefore distance travelled is $= 350 + 380 + 770 + 615 + 985$

$= 3100\text{ m}$

If previous allocation is considered, Bay 1 assigned to berth 1, Bay 2 assigned to berth 2, Bay 3 is assigned to berth 3, Bay 4 assigned to berth 4 and Bay 5 is assigned to berth 5.

**Original Allocation**

<table>
<thead>
<tr>
<th>Bay</th>
<th>Berth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
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<tr>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
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<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Here the distance travelled is $= 350 + 380 + 600 + 795 + 985$

$= 3110\text{ m}$

Hence the distance travelled has been reduced by 10m.

The bays can be assigned in a different manner.

Allocations are: Bay 1 is assigned to berth 2, Bay 2 is assigned to berth 1, Bay 3 is assigned to berth 4, Bay 4 is assigned to berth 3 and Bay 5 is assigned to berth 5.
Alternate Allocation

Table 8: Alternate Allocation

<table>
<thead>
<tr>
<th>Bay</th>
<th>Berth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
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<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
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<tr>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Even in this case, the total distance travelled is 3100m. Hence this is also an optimized solution.

Port management has options to allocate the vessel from bay 1 to bay 2 if earlier is already allotted is not available.

By assignment, the saving in distance is 10m while in actual practice, the saving can be more.

4. CONCLUSION

Before solving the problem using Assignment problem, the distance moved may vary. The distance is reduced by 10m. This reduction though small will have significant impact when there are a number of trips of the straddle carrier from the berth to the bay.

There are two alternatives for which the cost will be same. If allocations are random, distance travelled and subsequently the cost will substantially increase. By using assignment model for berth allocation, distance is reduced and we get a scientific solution. Thus management has flexibility in deciding the berths depending on availability.

A spreadsheet can be used to solve assignment model problems. Readymade software is also used to solve the problems. In this way, the methodology can be extended for a number of berths and a number of bays.

Thus solving assignment problem alternate solution can be attained. This will facilitate the port manager with more than one solution for the same cost.

5. REFERENCES


2. Xinjiang, China, August 8–12, 155–167.


