SHIP SIZE AND TURNROUND TIME

Some Empirical Evidence

By Trevor D. Heaver and Keith R. Studer

Ships of all types spend a large part of their lives in port, and this idle time adds substantially to the cost of providing shipping service. Technological progress has made possible the construction of larger, faster and more economical ships, but organisation and cargo handling in the ports have not kept pace. The linehaul savings achieved by larger vessels are too often negated by excessive idle time in port, during which many costs continue unabated.

The literature on ocean shipping contains many articles on the advantages of reducing port time. In particular, attention has been given to port improvements [1], [2], [3]; and many authors have given general indications of the proportion of time which vessels spend in port [4], [5], [6]. However, no systematic studies of vessel time in port are known to the authors of this article.

Some published statistics are available on rates of loading throughout the world. Bes has published statistics on various commodities and ports [7]; but his work is not of great value for analytical purposes. The information is supposedly for the guidance of charterers when stipulating a loading rate to be achieved under a particular charter party, but analysis of the sample presented for Vancouver, British Columbia, suggests that some of the data may mask rather than illuminate the real conditions.

The inadequacy of the statistics on vessel turnaround time has been referred to by Sturmeey in a letter responding to an article by Engelstad and Knudsen [8]. In that letter Sturmeey notes "the argument that port time must rise as ships get larger is an old and respectable one. I have never seen it subjected to rigorous empirical validation".

Because this dependence on size is so important, and because there is no quantitative evidence of its effects, the purpose of this study is to investigate it for a selection of ships which have loaded in the port of Vancouver.

SCOPE AND PURPOSE OF THE STUDY

One of the difficulties in research on turnaround time is the lack of access to relevant empirical data. For this study, it was found possible to obtain details – albeit crude ones – of the loading time of 1305 grain ships in Vancouver.¹ This sample constitutes the entire population of grain ships which loaded more than 5000 tons in the crop years from 1964–65 to 1967–68; of these observations more than one may refer to a given vessel, as some vessels called a number of times during the period. The restriction to loadings of over 5000 tons serves to ensure that the vessels, for the most part,

¹The data were made available by the British Columbia Grain Shippers' Clearance Association.
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are devoted entirely to grain, and general cargo liners loading only small parcels are excluded.

The information recorded in the primary data consisted of the vessel’s name, the month of arrival, the length of time spent loading, the number of berths visited, the total quantity and type of grain loaded, and the country of destination.

The types of vessels included in the sample range from small general purpose tramp ships to the largest bulk carriers designed specially for the handling of considerable quantities of homogeneous material; also, there is a proportion of tankers which had been diverted into the grain trade. Not quite all the vessels which appeared in the records were used in the study; for some the information given was incomplete, and others proved difficult to identify so that their size might be determined.

Using this information, this study has four purposes. The first is to provide a quantitative trial for Sturmeys “old and respectable” argument that larger vessels spend more time loading. The second is to examine the relationship between loading rate (measured in tons per day) and size of vessel: this will test the validity of the common assumption of a constant loading rate for vessels of different sizes. The third is to examine the effects on port turnaround time of certain factors exogenous to the vessel itself, such as type of cargo and number of berths visited. The fourth (and a very important) objective is to explore the implications of the results for the costs of loading vessels.

There are a number of reasons for concentrating on ships loading grain:

1. Compared to general cargo, grain presents a relatively uncomplicated loading process (if that can be believed)!
2. Grain is moved in ships of a fairly large range of sizes.
3. Most grain ships are filled to their deadweight capacity. Although there are some partial cargoes, this is less of a problem than with ships in the liner trade.
4. The grain transport system, of which ship loading is only a small part, is important to the port of Vancouver, and is also of some topical interest in view of the increasing severity of port tie-ups.
5. Because of the large grain shipments emanating from Vancouver, the necessary information proved to be available here.

DATA LIMITATIONS

It is necessary to recognise some of the grave weaknesses inherent in the primary data. Firstly, there is no consideration of the time spent by a vessel waiting for a berth, so it is not possible to investigate the hypothesis that congestion delays depend on size. Secondly, the time spent loading is registered only in days. This consistent rounding upward in the original data causes the loading rate to be understated and greatly reduces the sensitivity of the analysis. Thirdly, there is no record of the specific elevator at which a vessel loaded; since physical installations vary somewhat, this can be an important factor. Fourthly, there is no record of either the number of shifts or the number of loading belts used at the particular berth; thus, if a very high loading rate is observed, there is no way of telling whether the cost of achieving it was disproportionately high.

The data on vessels also have shortcomings. For the size of vessels the net register
tonnage is used in the form in which it appears in Lloyd's Register for the ship in question. The net register tonnage is a measure of the cargo carrying volume measured in units of 100 cubic feet. This representation of size is not without its disadvantages. Firstly, different nations have different formulas for calculating it. Secondly, net register tonnage gives a false picture (for technical reasons) of the size of open shelterdeck ships. Thirdly, although there is a fairly constant relationship of net register tonnage to deadweight capacity for small ships, deadweight being approximately 2½ times greater than net tonnage, this relationship is dependent upon the lines and layout of the vessel; therefore, it is not always possible to estimate the deadweight precisely from the net tonnage figure. Despite these objections, net register tonnage is the most convenient measure of vessel size, because it gives an idea of the space available for cargo; and it is readily available, whereas grain cubic capacity, for instance, is not.

The analysis of the shipping data is made difficult not only by the inherent heterogeneity of the vessels and port operations but by the frequent existence of unusual extraneous conditions. Exceptional conditions appear to be the rule in port affairs! In this study the data reflect port problems during the years 1965/66 and 1966/67. Labour difficulties slowed the flow of exports during the summer of 1965, and during the autumn a general shortage of box cars developed; over the whole winter, to compound the difficulty, there was a general shortage of certain grades of grain. In 1966 an eight-day railway strike beginning on 26 August hindered shipping, but this was only a prelude to the West Coast dock dispute, which stopped work for 21 days from 17 November.

THE PORT, SHIPS AND CARGOES

The Port

The harbour of Vancouver is situated on Burrard Inlet, the most southerly of British Columbia’s fiords. A major factor in the growth of the port has been the grain trade. The port is served by eight grain elevators with a storage capacity of close to 27 million bushels. The elevators have thirteen berths available to them, three of which are located alongside transit sheds, making it possible to handle grain and general cargo simultaneously. Grain shipments have been handled at a rate of over 200 million bushels a year, mostly wheat.

The Vessels

To appreciate the analysis of the loading rates it is necessary to have some impression of the physical features of the vessels loaded.

By far the greater part of the sample is made up of bulk carriers. Generally speaking, the vessels have sufficient volume to load down to their marks with grain of about 56 cubic feet per ton; their hatchways are large to facilitate access to the hold; the internal structure is self-cleaning and the holds self-trimming, to minimise stevedoring expense; there are a reasonable number of holds, to allow loading of different grains and also to ensure full holds even when a partial cargo is carried; the hatchways are of sufficient capacity to act as grain feeders, and this complies with the Grain Regulations with no need for the wooden structures which must be erected on conventional tramps [9]. The remainder of the dry cargo ships are conventional
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Tramp vessels without the advantages of bulk carriers. Most of them are full scantling vessels, but some are shelterdeckers which are of lighter construction. For the shelterdeckers net register tonnage gives a misleading impression of size.\(^2\)

A very small proportion of the sample is made up of tankers which came into the grain trade, although the heyday of the tanker as a carrier of grain occurred before the commencement of the study period. Thanks to the semi-liquid behaviour of granular materials, the storage of grain in tanks of such a ship is a practical proposition, even though loading and discharging usually take more time than for a dry bulk carrier.

An analysis of the ships involved in this study reveals that the growth in vessel size has not passed Vancouver by. The change in the average size of ships taking on grain cargoes is shown in Table 1. Between 1964 and 1967 the average size increased from 6524 N.R.T. to 7600 N.R.T.; but there was a decline in the average size in 1967/68, primarily because of the significant number of small Russian vessels loading grain in that year.

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>1964/65</th>
<th>Average Vessel Size – n.r.t.</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>6,363</td>
<td>6,510</td>
<td>7,187</td>
<td>6,638</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>7,295</td>
<td>8,501</td>
<td>7,862</td>
<td>7,544</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>6,361</td>
<td>7,593</td>
<td>7,545</td>
<td>7,445</td>
<td></td>
</tr>
<tr>
<td>Seeds</td>
<td>6,496</td>
<td>7,929</td>
<td>7,629</td>
<td>7,150</td>
<td></td>
</tr>
<tr>
<td>Overall Average</td>
<td>6,524</td>
<td>7,007</td>
<td>7,600</td>
<td>6,932</td>
<td></td>
</tr>
</tbody>
</table>

**The Cargoes**

For our purposes, the cargoes shipped fall into four categories:

1. Wheat cargoes involving only one grade, or at the most two grades, of wheat.
2. "Mixed" cargoes involving three or more different grades of wheat, with possibly small quantities of other grain in addition.
3. Barley cargoes, which are lighter than the others for a given volume.
4. Cargoes of oil seeds, such as rape, flax and mustard seeds. These cargoes sometimes include quantities of other grain, such as rye, oats or buckwheat.

Wheat is a dominating influence accounting for some 60 per cent of all tonnage shipped in each of the four years; mixed cargoes are next in importance, approximately equalling seeds with about 15 per cent each, and barley makes up the remainder.

\(^2\)In a full scantling vessel all cargo holds are beneath the main deck – the uppermost continuous watertight deck. The shelterdeck ship has a deck above the main deck in which there is a “tonnage opening”; this has no permanent closing device but must be secured with temporary covers. It is a convenient legal fiction that seas sweep through the tweendeck, which is not counted as cargo space in the measurement of register tonnage.

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The density of the cargo obviously has a bearing on the loading, since a greater bulk of the lighter commodities must be moved to make up a given weight. An idea of the effect of density on loading is given by the stowage factor of each material: that is, the amount of space in cubic feet occupied by one ton. Densities of cereals vary to some extent with the shipment area and the condition of the grain, particularly its moisture content; representative stowage factors are presented in Table 2,

**Table 2**

*Stowage Factors for Different Types of Grain*

<table>
<thead>
<tr>
<th>Type of Grain</th>
<th>Stowage Factor in Bulk Cubic Feet per Ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>45–48</td>
</tr>
<tr>
<td>Rye</td>
<td>48–50</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>51–53</td>
</tr>
<tr>
<td>Flaxseed</td>
<td>54–57</td>
</tr>
<tr>
<td>Barley</td>
<td>50–59</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>56–59</td>
</tr>
<tr>
<td>Oats (clipped)</td>
<td>60–65</td>
</tr>
<tr>
<td>Oats (unclipped)</td>
<td>70–72</td>
</tr>
</tbody>
</table>


**Table 3**

*Size Distribution of Grain Cargoes Studied, 1964–1968*

<table>
<thead>
<tr>
<th>Cargo Size Tons</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2,499</td>
<td>1</td>
<td>1</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td>2,500–4,999</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>5,000–7,499</td>
<td>10</td>
<td>7</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>7,500–9,999</td>
<td>18</td>
<td>22</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>10,000–12,499</td>
<td>60</td>
<td>58</td>
<td>47</td>
<td>36</td>
</tr>
<tr>
<td>12,500–14,999</td>
<td>113</td>
<td>139</td>
<td>143</td>
<td>130</td>
</tr>
<tr>
<td>15,000–17,499</td>
<td>19</td>
<td>18</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>17,500–19,999</td>
<td>30</td>
<td>36</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>20,000–22,499</td>
<td>29</td>
<td>29</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>22,500–24,999</td>
<td>8</td>
<td>13</td>
<td>30</td>
<td>17</td>
</tr>
<tr>
<td>25,000–29,999</td>
<td>5</td>
<td>13</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>30,000–34,999</td>
<td>—</td>
<td>7</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>35,000–39,999</td>
<td>—</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>40,000 and over</td>
<td>—</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>300</td>
<td>347</td>
<td>342</td>
<td>316</td>
</tr>
</tbody>
</table>

| Mean load | 14,310 | 15,410 | 16,280 | 14,900 |
| Standard deviation | 4,686 | 5,497 | 7,169 | 7,287 |
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in which it can be seen that wheat is the heaviest grain and that an equivalent weight of clipped oats, for example, will occupy approximately half as much space again.

The actual distribution of load sizes observed in the sample is presented in Table 3. For each crop year the range of observations is considerable, and it is noticeable that the dispersion increases with the passage of time. The largest cargo loaded in 1964/65 amounted to some 29,000 tons, whereas the largest cargo loaded in 1967/68 was 84,000 tons aboard the Sigeilmer. The modal tonnage has remained the same at about 13,750 tons.

CHARACTERISTICS OF THE GRAIN LOADINGS

Distribution of Loading Rates

The loading rates observed ranged from approximately 900 tons per day to around 9,500 tons per day (Table 4). There is a marked tendency for the number of higher loading rates to increase in the later years, and the modal rate increased from 2,500 to 3,500 tons per day in 1967/68. The overall average loading rate improved by almost 10 per cent between 1964 and 1968 (Table 5). It is also noticeable that the standard deviation of the observations has been increasing as the number of high loading rates has increased.

The overall loading rate can be very misleading, as is shown in Table 5, because the differences between commodity types are substantial. One or two grades of wheat generally provide no problem. When three or more grades of wheat are involved there is understandably a greater delay. Cargoes of assorted oil seeds are usually

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**Table 4**

_Distribution of Observed Loading Rates for all Grain Cargoes, 1964–1968_

<table>
<thead>
<tr>
<th>Loading Rate</th>
<th>Number of Cargoes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons/day</td>
<td>1964/65</td>
</tr>
<tr>
<td>0–999</td>
<td>1</td>
</tr>
<tr>
<td>1,000–1,999</td>
<td>3</td>
</tr>
<tr>
<td>2,000–2,999</td>
<td>110</td>
</tr>
<tr>
<td>3,000–3,999</td>
<td>94</td>
</tr>
<tr>
<td>4,000–4,999</td>
<td>42</td>
</tr>
<tr>
<td>5,000–5,999</td>
<td>15</td>
</tr>
<tr>
<td>6,000–6,999</td>
<td>4</td>
</tr>
<tr>
<td>7,000–7,999</td>
<td>2</td>
</tr>
<tr>
<td>8,000–8,999</td>
<td>—</td>
</tr>
<tr>
<td>9,000 and above</td>
<td>1</td>
</tr>
</tbody>
</table>

**Total** | 300 | 347 | 342 | 316 |
Table 5
Average Loading Rates by Commodity Type, 1964–1968

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Average Loading Rate Tons per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1964/65</td>
</tr>
<tr>
<td>Wheat</td>
<td>3,533</td>
</tr>
<tr>
<td></td>
<td>(1,132)*</td>
</tr>
<tr>
<td>Mixed</td>
<td>3,305</td>
</tr>
<tr>
<td></td>
<td>(1,085)</td>
</tr>
<tr>
<td>Barley</td>
<td>2,672</td>
</tr>
<tr>
<td></td>
<td>(738)</td>
</tr>
<tr>
<td>Seeds</td>
<td>1,939</td>
</tr>
<tr>
<td></td>
<td>(632)</td>
</tr>
<tr>
<td>Total</td>
<td>3,272</td>
</tr>
<tr>
<td></td>
<td>(1,159)</td>
</tr>
</tbody>
</table>

*Bracketed figures are the standard deviation.

made up of various small batches, and this slows the loading process considerably; barley is a light cargo, and so requires more bulk to be shifted for an equivalent load measured by weight. The difference between the extremes of wheat and seeds can be seen clearly; in 1967/68 the average loading rate for wheat cargoes was 3,962 tons per day, whereas the average loading rate for seed was only 2,302 tons per day. It is interesting to note that improvements have occurred in each year for every cargo type, with only one exception. The average loading rate for mixed grades of wheat declined in 1967/68 from 3,615 to 3,586 tons per day – not a very significant decline.

Distribution of Loading Times
Because of the limitations in the accessible data, the time which vessels spend loading is measured only to the nearest day. The distribution of loading times differs significantly among the commodity types (Table 6). Having regard to the changes in the average size of cargo, there has been a significant improvement in loading times over the four-year period. The average loading time for wheat was 4-10 days in 1964 for an average cargo of 14,120 tons, and 3-65 days in 1967/68 for an average cargo of 14,410 tons; for seeds, the average loading time in 1965/65 was 6-5 days for an average cargo of 12,730 tons, and in 1967/68 it was 6-02 days for an average cargo of 13,740 tons. The loading time for barley during this period increased from 5-07 days to 5-45 days, but the average size of barley cargoes had increased by some 28 per cent.

Frequency of Berth Changes
The necessity for a change of berth adds considerably to the time required to load a vessel. Table 7 shows the distribution of berth movements for all types of grain

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Table 6

Distribution of Observed Loading Times by Commodity Type, 1967–1968

<table>
<thead>
<tr>
<th>Loading Time Days</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wheat</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>—</td>
</tr>
<tr>
<td>9</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td>191</td>
</tr>
</tbody>
</table>

Mean loading time 3·65 4·42 5·45 6·02 4·17
Standard deviation 0·97 1·05 1·13 2·57 1·45

Table 7

Distribution of Berths Visited per Ship, all Observed Grain Cargoes, 1964–1968

<table>
<thead>
<tr>
<th>Berths Visited</th>
<th>Number of Vessels</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>83</td>
<td>85</td>
<td>97</td>
<td>103</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>143</td>
<td>136</td>
<td>149</td>
<td>132</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>56</td>
<td>96</td>
<td>81</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>15</td>
<td>26</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>2</td>
<td>4</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>1</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>300</td>
<td>347</td>
<td>342</td>
<td>316</td>
</tr>
</tbody>
</table>

Mean berths visited 2·05 2·21 2·05 1·98
Standard deviation 0·88 0·94 0·83 0·87

Shipments. It can be seen that two berths per ship is the modal value for each crop year analysed, and that the average number of berths for each vessel is also in the neighbourhood of two. The number of berths visited is related to the type of cargo loaded, as indicated by Table 8.
Table 8
Average Number of Berths Used per Cargo by Commodity Type, 1964–1968

<table>
<thead>
<tr>
<th>Cargo Type</th>
<th>Average Number of Berths Visited</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1964/65</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.92</td>
</tr>
<tr>
<td>Mixed</td>
<td>2.15</td>
</tr>
<tr>
<td>Barley</td>
<td>1.87</td>
</tr>
<tr>
<td>Seeds</td>
<td>3.04</td>
</tr>
</tbody>
</table>

Average number of berth visits for all cargoes

2.05      2.21      2.05      1.98

The results for each type of cargo are reasonably consistent over the period covered by the data. Wheat is the best performer with an average of rather less than two berths per load, while seeds require the most changes with an average of about three berths per load. There seems to be a trend towards fewer berthing per cargo, except for barley.

Analysis of Loading Time and Vessel Size

The analysis of the data is divided into three main parts. First, the relation of loading days to ship size and load will be examined. Secondly the relationship between vessel size and loading rate will be examined, because the data are amenable to further analysis. The third part of the study introduces the additional factor of the number of berths visited. This is combined with ship and load size to give a better explanation of the total loading time.

Vessel Size and Loading Time

The first hypothesis of this paper suggests that larger ships spend more time loading than smaller ones. This would seem to be intuitively the case, since larger ships carry a larger cargo and, therefore, might occupy a given set of shore-based handling gear for a longer period. The hypothesis appears to be supported by the observable pattern in the average number of loading days, which increased from 4.50 to 4.74 days over the first three years but fell to 4.17 days in 1967/68, the year in which the average vessel size declined. The results of regressing ship size against loading time are shown in Table 9. On the whole the proportion of loading time which can be attributed to the ship size is very low. The highest R² value (0.49) is for mixed grain in 1967/68; several of the regressions are not statistically significant. The most consistent results are obtained for wheat, possibly because of the lack of complication in the loading processes, but more probably because of the large number of observations for each year.

If ship load is regressed against loading time some improvement is obtained in almost every case (Table 10). Sometimes the relationship accounts for some 50 per cent of the variation in loading time.
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**Table 9**

Regression Coefficients in the Relation between Ship Size and Loading Time*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>Regression Coefficients</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>A</td>
<td>2·43</td>
<td>3·40</td>
<td>2·95</td>
<td>2·86</td>
</tr>
<tr>
<td></td>
<td>(0·28)</td>
<td>(0·25)</td>
<td>(0·19)</td>
<td>(0·14)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^−3)</td>
<td>0·26</td>
<td>0·14</td>
<td>0·20</td>
<td>0·12</td>
</tr>
<tr>
<td></td>
<td>(0·04)</td>
<td>(0·04)</td>
<td>(0·02)</td>
<td>(0·02)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R^2</td>
<td>0·16</td>
<td>0·06</td>
<td>0·25</td>
<td>0·18</td>
</tr>
<tr>
<td>Mixed</td>
<td>A</td>
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<td>3·82</td>
<td>3·51</td>
<td>3·00</td>
</tr>
<tr>
<td></td>
<td>(0·86)</td>
<td>(1·10)</td>
<td>(0·38)</td>
<td>(0·25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^−3)</td>
<td>0·15</td>
<td>0·29</td>
<td>0·19</td>
<td>0·19</td>
</tr>
<tr>
<td></td>
<td>(0·11)</td>
<td>(0·12)</td>
<td>(0·05)</td>
<td>(0·03)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R^2</td>
<td>0·03†</td>
<td>0·12†</td>
<td>0·24†</td>
<td>0·49†</td>
</tr>
<tr>
<td>Barley</td>
<td>A</td>
<td>5·11</td>
<td>2·53</td>
<td>3·44†</td>
<td>4·88</td>
</tr>
<tr>
<td></td>
<td>(0·93)</td>
<td>(1·25)</td>
<td>(0·83)</td>
<td>(0·54)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^−3)</td>
<td>−0·01</td>
<td>0·50</td>
<td>0·24†</td>
<td>0·08</td>
</tr>
<tr>
<td></td>
<td>(0·14)</td>
<td>(0·16)</td>
<td>(0·10)</td>
<td>(0·07)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R^2</td>
<td>0·00†</td>
<td>0·31</td>
<td>0·10†</td>
<td>0·05†</td>
</tr>
<tr>
<td>Seeds</td>
<td>A</td>
<td>4·49</td>
<td>4·88</td>
<td>7·14†</td>
<td>2·15</td>
</tr>
<tr>
<td></td>
<td>(1·84)</td>
<td>(0·77)</td>
<td>(1·03)</td>
<td>(0·91)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^−3)</td>
<td>0·33</td>
<td>0·34</td>
<td>0·03</td>
<td>0·54</td>
</tr>
<tr>
<td></td>
<td>(0·27)</td>
<td>(0·09)</td>
<td>(0·13)</td>
<td>(0·12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R^2</td>
<td>0·06†</td>
<td>0·26</td>
<td>0·00†</td>
<td>0·35†</td>
</tr>
</tbody>
</table>

*The relationship is of the form:

\[
(\text{Loading Time}) = A + B \times \text{(Ship Size)}
\]

where loading time is measured in days and ship size in net register tons. The constant A is, therefore, measured in days and B in days per net register ton. The standard errors of the coefficients are in parentheses.

†Not significant at the 1% level.

The regressions certainly support the general hypothesis that ship loading time increases with the size of the vessel. But in general only a small proportion of the variation in loading time is accounted for by vessel size. A significant amount of the time can be accounted for by operations which are largely constant per vessel, and many of the variations are accounted for by variables other than size. In an examination of the Vancouver data for four types of grain cargo over four years, it is evident that significant differences exist between the types of grain and that conditions affecting average loading times varied significantly from one year to another. The improvement in nearly all the regressions when ship load is regressed against loading time occurs because with partial cargoes ship load is a more precise measure of the amount of work done.
### Table 10

*Regression Coefficients in the Relation between Ship Load and Loading Time*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat A</td>
<td>2.17</td>
<td>3.22</td>
<td>2.87</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>(0.22)</td>
<td>(0.24)</td>
<td>(0.18)</td>
<td>(0.13)</td>
</tr>
<tr>
<td>B ($x10^{-3}$)</td>
<td>0.14</td>
<td>0.07</td>
<td>0.09</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>R²</td>
<td>0.31</td>
<td>0.08</td>
<td>0.28</td>
<td>0.25</td>
</tr>
<tr>
<td>Mixed A</td>
<td>4.11</td>
<td>3.63</td>
<td>3.64</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(1.14)</td>
<td>(0.37)</td>
<td>(0.24)</td>
</tr>
<tr>
<td>B ($x10^{-3}$)</td>
<td>0.07</td>
<td>0.14</td>
<td>0.08</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(0.05)</td>
<td>(0.06)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>R²</td>
<td>0.04†</td>
<td>0.13†</td>
<td>0.21</td>
<td>0.56</td>
</tr>
<tr>
<td>Barley A</td>
<td>3.96</td>
<td>1.62</td>
<td>2.47</td>
<td>4.85</td>
</tr>
<tr>
<td></td>
<td>(0.98)</td>
<td>(1.00)</td>
<td>(0.75)</td>
<td>(0.56)</td>
</tr>
<tr>
<td>B ($x10^{-3}$)</td>
<td>0.08</td>
<td>0.29</td>
<td>0.18</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.06)</td>
<td>(0.04)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>R²</td>
<td>0.05†</td>
<td>0.52</td>
<td>0.35</td>
<td>0.03†</td>
</tr>
<tr>
<td>Seeds A</td>
<td>3.10</td>
<td>4.71</td>
<td>5.52</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>(1.01)</td>
<td>(0.68)</td>
<td>(1.03)</td>
<td>(0.56)</td>
</tr>
<tr>
<td>B ($x10^{-3}$)</td>
<td>0.28</td>
<td>0.18</td>
<td>0.12</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.04)</td>
<td>(0.06)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>R²</td>
<td>0.37</td>
<td>0.35</td>
<td>0.08†</td>
<td>0.56</td>
</tr>
</tbody>
</table>

*The relationship is of the form:

\[(\text{Loading time}) = A + B (\text{Ship Load})\]

where loading time is measured in days and ship load in tons. The constant A is, therefore, in days and B in days per ton. The standard errors of the coefficients are in parentheses.

†Not statistically significant at the 1% level.

The generally poor level of explanation shown in the regressions is due to four factors:

1. There are many extraneous factors influencing the loading time for any particular ship: a few examples are weather, labour conditions, grain supply, the importance of time to vessel operations, and the number of berth changes.
2. The dispersion of loading times achieved is influenced by the structure of the group of vessels: for example, the proportions of tankers and specialised bulk carriers.
3. The relationship between loading time and ship size or ship load might be anticipated to be non-linear. However, the scatter of observations and the
visual pattern of the data make it most unlikely that any non-linear relationship would produce a better fit in general.

4. The limitations in the data, particularly the discrete nature of the loading time data, may mask the relationships.

**Vessel Size and Loading Rates**

The general pattern of loading rates is shown in Figure 1. Scanning the observations reveals that there is a distinct tendency for loading rates to increase with ship size, as would be expected from the results of the analysis of loading time.

The relationship can be quantified by regression analysis, the results of which are shown in Tables 11 and 12. Again the results achieved by regressing ship load are better than those of vessel size, because of the problem of partial cargoes, while the reliability of these regressions is better than those for loading time.

The level of explanation is highest (0.79) for mixed grains in 1967/68. With the exception of seed grains the results are best for the last year. This suggests improvements in dispatching techniques, and it is particularly encouraging that it occurs for wheat, the dominant cargo type. Table 12 suggests that in half the cases 40 per cent or more of the variation in loading rate is explained by ship size. This shows that there are many circumstances which can cause variations in the rate of ship loading, and the next section will examine the influence of one of these variables, the number of berths visited.
Table 11

Regression Coefficients in the Relation between Ship Size and Loading Rate*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1647</td>
<td>874</td>
<td>1958</td>
<td>1427</td>
</tr>
<tr>
<td></td>
<td>(260)</td>
<td>(256)</td>
<td>(198)</td>
<td>(196)</td>
</tr>
<tr>
<td>B</td>
<td>0.30</td>
<td>0.41</td>
<td>0.25</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.04)</td>
<td>(0.02)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>R²</td>
<td>0.23</td>
<td>0.34</td>
<td>0.33</td>
<td>0.53</td>
</tr>
<tr>
<td>Mixed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1477</td>
<td>1348</td>
<td>1020</td>
<td>1497</td>
</tr>
<tr>
<td></td>
<td>(584)</td>
<td>(625)</td>
<td>(376)</td>
<td>(187)</td>
</tr>
<tr>
<td>B</td>
<td>0.25</td>
<td>0.23</td>
<td>0.33</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.07)</td>
<td>(0.04)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>R²</td>
<td>0.18</td>
<td>0.21</td>
<td>0.50</td>
<td>0.79</td>
</tr>
<tr>
<td>Barley</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1162</td>
<td>2298</td>
<td>1887</td>
<td>817</td>
</tr>
<tr>
<td></td>
<td>(588)</td>
<td>(473)</td>
<td>(411)</td>
<td>(336)</td>
</tr>
<tr>
<td>B</td>
<td>0.24</td>
<td>0.05</td>
<td>0.16</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td>(0.06)</td>
<td>(0.05)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>R²</td>
<td>0.20†</td>
<td>0.04†</td>
<td>0.25</td>
<td>0.59</td>
</tr>
<tr>
<td>Seeds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>642</td>
<td>1088</td>
<td>65</td>
<td>1204</td>
</tr>
<tr>
<td></td>
<td>(440)</td>
<td>(247)</td>
<td>(356)</td>
<td>(257)</td>
</tr>
<tr>
<td>B</td>
<td>0.20</td>
<td>0.13</td>
<td>0.29</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.07)</td>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>R²</td>
<td>0.28</td>
<td>0.35</td>
<td>0.51</td>
<td>0.34</td>
</tr>
</tbody>
</table>

*The relation is of the form:
(Loading rate in tons per day) = A + B (ship size)

†Not significant at the 1% level.

Movement between Berths

Basically, there are two underlying causes of a berth change. The size of a vessel may be too great for it to be filled at any one elevator, or the diverse nature of the cargo may require visits to different berths. The first factor contributes towards lengthening the loading time of large vessels in particular, but the second factor is applicable to any size of vessel.

The relationship between berth changes and cargo type is presented in Table 8; the increase in the number of berths visited for the more complicated cargoes can be seen clearly. The occurrence of a berth change not only adds to costs directly but also adds to the time required for loading. An idea of this impact is obtained by the two-variable regression model:

Loading time = A + B (ship load) + C (berths visited)
SHIP SIZE AND TURNROUND TIME

Trevor D. Heaver and Keith R. Studer

Table 12
Regression Coefficients in the Relation between Ship Load and Loading Rate*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat A</td>
<td>1599</td>
<td>602</td>
<td>1868</td>
<td>1147</td>
</tr>
<tr>
<td></td>
<td>(207)</td>
<td>(231)</td>
<td>(192)</td>
<td>(175)</td>
</tr>
<tr>
<td>B</td>
<td>0.14</td>
<td>0.20</td>
<td>0.12</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>R²</td>
<td>0.33</td>
<td>0.43</td>
<td>0.37</td>
<td>0.63</td>
</tr>
<tr>
<td>Mixed A</td>
<td>801</td>
<td>1157</td>
<td>986</td>
<td>1444</td>
</tr>
<tr>
<td></td>
<td>(507)</td>
<td>(642)</td>
<td>(340)</td>
<td>(192)</td>
</tr>
<tr>
<td>B</td>
<td>0.15</td>
<td>0.11</td>
<td>0.15</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>R²</td>
<td>0.36</td>
<td>0.24</td>
<td>0.36</td>
<td>0.79</td>
</tr>
<tr>
<td>Barley A</td>
<td>357</td>
<td>2121</td>
<td>1802</td>
<td>625</td>
</tr>
<tr>
<td></td>
<td>(598)</td>
<td>(448)</td>
<td>(412)</td>
<td>(321)</td>
</tr>
<tr>
<td>B</td>
<td>0.18</td>
<td>0.04</td>
<td>0.08</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>R²</td>
<td>0.40</td>
<td>0.08†</td>
<td>0.27</td>
<td>0.65</td>
</tr>
<tr>
<td>Seeds A</td>
<td>823</td>
<td>1021</td>
<td>417</td>
<td>1489</td>
</tr>
<tr>
<td></td>
<td>(249)</td>
<td>(209)</td>
<td>(437)</td>
<td>(203)</td>
</tr>
<tr>
<td>B</td>
<td>0.09</td>
<td>0.07</td>
<td>0.12</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.01)</td>
<td>(0.03)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>R²</td>
<td>0.49</td>
<td>0.46</td>
<td>0.33</td>
<td>0.34</td>
</tr>
</tbody>
</table>

*The relation is of the form:

\[(\text{Loading rate in tons per day}) = A + B (\text{ship load})\]

†Not significant at the 1% level.

The results of this regression are presented in Table 13. By comparison with Table 10 the results have improved in every case, in most instances substantially. This would be expected, since the internal logic of the model has improved.

The impact of berth changes on loading time of the various types of grain is fairly consistent, except that seeds experience a somewhat higher general delay. Considering a working day to be made up of eight hours, the results for wheat imply a delay of between four and six hours for each change of berth.

A similar model can be constructed for loading rates (Table 14). Table 14 has the highest $R^2$ values obtained in this study; eleven of the regressions have $R^2$ values of 0.5 or higher, and all but two (barley in 1965/66 and 1966/67) have a value of over 0.41.

For evaluating the degree of explanation achieved by the simple regressions used in this study, the imperfections in the data and the inherent complexity of the port
Table 13
Regression Coefficients in the Relation between Loading Time, Ship Load, and Number of Berths Visited*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>Regression Coefficients</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>A</td>
<td>1.63</td>
<td>2.40</td>
<td>1.96</td>
<td>1.78</td>
</tr>
<tr>
<td></td>
<td>(0.21)</td>
<td>(0.25)</td>
<td>(0.27)</td>
<td>(0.15)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^-4)</td>
<td>0.81</td>
<td>0.52</td>
<td>0.80</td>
<td>0.70</td>
</tr>
<tr>
<td></td>
<td>(0.10)</td>
<td>(0.14)</td>
<td>(0.12)</td>
<td>(0.07)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.67</td>
<td>0.57</td>
<td>0.60</td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td>(0.08)</td>
<td>(0.08)</td>
<td>(0.11)</td>
<td>(0.08)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R²</td>
<td>0.45</td>
<td>0.23</td>
<td>0.29</td>
<td>0.52</td>
</tr>
<tr>
<td>Mixed</td>
<td>A</td>
<td>2.71</td>
<td>0.40</td>
<td>2.68</td>
<td>2.04</td>
</tr>
<tr>
<td></td>
<td>(0.75)</td>
<td>(1.20)</td>
<td>(0.40)</td>
<td>(0.33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^-4)</td>
<td>0.57</td>
<td>1.31</td>
<td>0.59</td>
<td>0.79</td>
</tr>
<tr>
<td></td>
<td>(0.31)</td>
<td>(0.47)</td>
<td>(0.18)</td>
<td>(0.14)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.73</td>
<td>1.33</td>
<td>0.60</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.30)</td>
<td>(0.14)</td>
<td>(0.15)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R²</td>
<td>0.22</td>
<td>0.41</td>
<td>0.41</td>
<td>0.61</td>
</tr>
<tr>
<td>Barley</td>
<td>A</td>
<td>2.85</td>
<td>1.15</td>
<td>1.72</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>(0.64)</td>
<td>(1.05)</td>
<td>(0.86)</td>
<td>(0.78)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^-4)</td>
<td>0.63</td>
<td>2.47</td>
<td>1.55</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>(0.32)</td>
<td>(0.65)</td>
<td>(0.46)</td>
<td>(0.33)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.73</td>
<td>0.51</td>
<td>0.57</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>(0.26)</td>
<td>(0.39)</td>
<td>(0.36)</td>
<td>(0.25)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R²</td>
<td>0.33</td>
<td>0.56</td>
<td>0.41</td>
<td>0.33</td>
</tr>
<tr>
<td>Seeds</td>
<td>A</td>
<td>0.80</td>
<td>3.13</td>
<td>2.80</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>(0.83)</td>
<td>(0.94)</td>
<td>(1.17)</td>
<td>(0.64)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B (x10^-4)</td>
<td>1.35</td>
<td>1.47</td>
<td>0.72</td>
<td>1.92</td>
</tr>
<tr>
<td></td>
<td>(0.42)</td>
<td>(0.39)</td>
<td>(0.56)</td>
<td>(0.52)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>1.35</td>
<td>0.67</td>
<td>1.14</td>
<td>0.97</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.29)</td>
<td>(0.31)</td>
<td>(0.31)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R²</td>
<td>0.70</td>
<td>0.43</td>
<td>0.31</td>
<td>0.71</td>
</tr>
</tbody>
</table>

*The relationship is of the form:

\[(\text{Loading time in days}) = A + B \cdot (\text{ship load}) + C \cdot (\text{berths visited})\]

operations must be kept in mind. The regressions certainly support the hypothesis that loading time increases with ship size and that loading rate also increases with ship size. However, it is also very obvious that many factors other than ship size are significant. It is most important that such factors be identified, so that the economics of vessel size will not be offset by unnecessary port delays.

The implications for vessel costs of the characteristics of loading time revealed in this study are examined in the next section.
**SHIP SIZE AND TURNROUND TIME**

Trevor D. Heaver and Keith R. Studer

**Table 14**

*Regression Coefficients in the Relation between Loading Rate, Ship Load, and Number of Berths Visited*

<table>
<thead>
<tr>
<th>Type of Cargo</th>
<th>1964/65</th>
<th>1965/66</th>
<th>1966/67</th>
<th>1967/68</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wheat</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2113</td>
<td>1437</td>
<td>2249</td>
<td>2438</td>
</tr>
<tr>
<td></td>
<td>(203)</td>
<td>(240)</td>
<td>(270)</td>
<td>(239)</td>
</tr>
<tr>
<td>B</td>
<td>0.17</td>
<td>0.23</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>C</td>
<td>-536.9</td>
<td>-580.4</td>
<td>-578.5</td>
<td>-433.0</td>
</tr>
<tr>
<td></td>
<td>(77)</td>
<td>(81)</td>
<td>(109)</td>
<td>(121)</td>
</tr>
<tr>
<td>R²</td>
<td>0.58</td>
<td>0.54</td>
<td>0.48</td>
<td>0.51</td>
</tr>
<tr>
<td><strong>Mixed</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1905</td>
<td>3176</td>
<td>1826</td>
<td>1915</td>
</tr>
<tr>
<td></td>
<td>(450)</td>
<td>(636)</td>
<td>(369)</td>
<td>(267)</td>
</tr>
<tr>
<td>B</td>
<td>0.14</td>
<td>0.12</td>
<td>0.17</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>C</td>
<td>-473.4</td>
<td>-833.4</td>
<td>-538.6</td>
<td>-352.3</td>
</tr>
<tr>
<td></td>
<td>(140)</td>
<td>(161)</td>
<td>(129)</td>
<td>(119)</td>
</tr>
<tr>
<td>R²</td>
<td>0.59</td>
<td>0.54</td>
<td>0.66</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>Barley</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1680</td>
<td>2328</td>
<td>2223</td>
<td>1566</td>
</tr>
<tr>
<td></td>
<td>(347)</td>
<td>(469)</td>
<td>(474)</td>
<td>(438)</td>
</tr>
<tr>
<td>B</td>
<td>0.14</td>
<td>0.05</td>
<td>0.09</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>C</td>
<td>-493.3</td>
<td>-224.3</td>
<td>-325.1</td>
<td>-569.6</td>
</tr>
<tr>
<td></td>
<td>(143)</td>
<td>(175)</td>
<td>(196)</td>
<td>(142)</td>
</tr>
<tr>
<td>R²</td>
<td>0.71</td>
<td>0.14†</td>
<td>0.33</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>Seeds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>1332</td>
<td>1411</td>
<td>1365</td>
<td>2120</td>
</tr>
<tr>
<td></td>
<td>(226)</td>
<td>(297)</td>
<td>(524)</td>
<td>(224)</td>
</tr>
<tr>
<td>B</td>
<td>0.12</td>
<td>0.08</td>
<td>0.13</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>(0.01)</td>
<td>(0.01)</td>
<td>(0.03)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>C</td>
<td>-284.4</td>
<td>-164.3</td>
<td>-396.3</td>
<td>-386.6</td>
</tr>
<tr>
<td></td>
<td>(62)</td>
<td>(91)</td>
<td>(140)</td>
<td>(107)</td>
</tr>
<tr>
<td>R²</td>
<td>0.82</td>
<td>0.50</td>
<td>0.44</td>
<td>0.42</td>
</tr>
</tbody>
</table>

*The relationship is of the form:

(Loading rate in tons per day) = A + B (ship load) + C (berths visited)

†Not significant at the 1% level.

**IMPLICATIONS FOR SHIPPING COSTS**

The time taken to load a vessel is costly to the owners, because certain costs (they may be outlays or opportunity costs) are incurred irrespective of the amount of work actually done; these costs may be referred to as time costs. By combining time costs for different sizes of vessels with the vessel loading rates obtained in this study, we can estimate the time costs of loading cargo for different sized ships.

If the time costs of loading are to fall with increasing ship size it is not sufficient that loading rate merely increases with size; it must increase at a rate which more than
compensates for the greater operating costs of a larger ship. By using costs estimates and the figures for port time obtained in this study, it is possible to calculate the costs of loading times.

The daily vessel costs used are derived from the costs of bulk carriers estimated by Heaver [10]. The costs include all expenses except fuel costs at sea and allow for taxes and an 8 per cent return on ship owner’s equity. The vessel life is assumed to be fifteen years. Assuming that a vessel takes up its full deadweight capacity in cargo, the total loading time for different sizes of vessels at different loaded rates can be calculated; multiplying this by daily costs gives a total cost of loading time. The family of curves in Figure 2 shows the cost for different ship sizes at different loading rates. From these the time cost per ton of cargo loaded can be estimated.

The estimated cost per ton for a given shipload can be obtained by using Figure 2 and Table 12. To ensure that values can be read off the computed lines in Figure 2, an arbitrary loading rate is selected (but one for which a curve is plotted in Figure 2).

3In view of the more explanatory two-variable regression incorporating berth changes it might be argued that this would be a better basis on which to work. But this more sophisticated regression leads to a closely spaced family of curves of very similar shape to the ones obtained above, but with one member of the family for each possible number of berths visited. Considering the very approximate costs figures used and that the stated objectives are merely to investigate the form of the relationship, the values in Table 12 are considered adequate.
and a ship size appropriate to it is calculated from the regression equation in Table 12. For this ship size and loading rate a cost per ton can be read off the curve in Figure 2.4 Performing this task several times for each cargo type in the years studied gives rise to the curves shown in Figures 3 to 6. In general the curves support the hypothesis that cargo loading costs decline as vessel size increases.

4For example, in 1964/65 a loading rate of 3,000 tons a day might have been achieved by a vessel of 10,007 tons; that is, \( (3,000 - 1,599)/(0.14) = 10,007 \) from Table 12. Reading off Figure 2, that vessel would have incurred a cost of 63 cents per cargo ton. A 4,000 tons a day loading rate would have been achieved by a vessel of 17,150 tons \( [(4,000 - 1,599)/(0.14)] \), which would have incurred a cost of 38 cents per cargo ton.
January 1972

The danger to be avoided is the extrapolation of regression lines beyond the region in which data were available. This places an upper limit of around 35,000 tons on the size of ships for which costs can be estimated. It is not pretended that these costs are accurate: firstly because reported costs are in general only an approximation, secondly because actual costs differ considerably between individual vessels of the same type, and thirdly because the regression line is only an estimate of the loading rate. It is felt, however, that although these results are crude they do indicate the form of the relationship, which is determined not by the figures but by the relative gradients of the respective functions. Changes in these gradients (for example, the extent to which larger vessels achieve a higher loading rate) could have a significant effect on the shape of the curves. The efficiency of port operations becomes important then. Slower loading rates (or more likely unloading rates) for large vessels could cause the relative advantage of large vessels to be negated.

SUMMARY

The data available for vessels loading grain in Vancouver over the years 1964 to 1967 have enabled evidence to be presented that large vessels spend a longer period in port than their smaller counterparts but achieve a higher loading rate. The extent of this difference appears to be sufficiently great for vessel time costs per ton of cargo loaded to diminish as vessel size increases. The study also indicates that, while loading performance improved during the four-year period, loading rates differed significantly according to the specific types of grain loaded. It is clear that charterers must be concerned with the particulars of the grain cargo when estimating loading rates to be achieved.

REFERENCES


University of British Columbia

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