Efficiency of Log Vessel Loading Operations: A Loader Configuration Case Study

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Abstract
Almost 50% of New Zealand’s 23.5 Million m³ harvested volume is exported directly as roundwood (logs). Not only is port cost-effectiveness important in terms of remaining internationally competitive, but capacity and capability of the ports is critical in supporting the expected growth in the industry. In terms of port operations, one important aspect is optimising the delivery of logs to the vessel with the crane loading capability. A detailed time and motion study was completed at the Port of Nelson on both the loaders delivering logs to the bunks alongside the vessel, as well as the four on-board cranes heaving the log bundles during the loading of the 30,000 tonne capacity Rattana Naree vessel. The current log delivery configuration of four-loaders (two large 17 tonne capacity and two ‘small’ 14 tonne max. capacity) was compared to just two large loaders. The study focussed on cycle times and delays to assess the impact of the loader configurations on both loader and crane efficiency. The average loader cycle time with four loaders was 3.2 minutes, compared to 2.6 minutes with two loaders. Utilisation rates were 69% and 74% respectively. Operational delays were primarily responsible for the difference, with 29% change in operational delays associated with the bunks being full, indicating excess loader capacity. For the cranes, heave rates were 6.4 with four loaders and 9.1 heaves per hour with two loaders. Change in productivity will be significantly less given that the four loader configuration double loaded (one large, one small delivery to each bunk) resulting in larger average payload per heave. However the four loader configuration did reduce crane utilisation by 15%; the larger bunk loads requiring more ‘butting’, which is the process of a squaring up the all the logs in the bunk prior to heaving the load onto the vessel. Overall, a conclusion can be made that the two-loader configuration was a more efficient option that had no adverse impacts on crane delays.

Introduction
New Zealand currently exports 13 million m³ of roundwood (logs) through 15 ports. As demand for export logs continue to increase there are significant opportunities to increase export earnings, currently NZ third largest (NZFOA 2012). In order to capitalise on the increasing demand, on-port operations will need to increase infrastructure and or improve existing operations to accommodate the expected growth in export of logs. The port environment poses a unique set of difficulties, mainly spatial constraints, to vessel loading operations that restrict the number of feasible solutions to improving productivity. One option is to increase the efficiencies of vessel-loading operations through optimising the current system.

Log delivery is a port operation during vessel loading that retrieves logs from on-port storage and delivers them to bunks on the wharf next to the vessel to be loaded. At this point stevedores operate on-board cranes to load the vessel, with a small excavator based grapple (‘digger’) operating
in the hold to fleet and stow the loaded logs. Vessel have a high daily charge out rate (approx US$20,000 per day) and as such quick and efficient loading is important. It is important to have sufficient loader capacity to ensure no adverse impacts on productivity to stevedore operations. However, there is uncertainty on what the most efficient and cost-effective loading configuration is for loaders when delivering logs to the crane loading area (Figure 1). Both capability and cost-effectiveness of loading log vessels is a sector of the forestry supply chain where few studies have been made. This study seeks to begin to fill the gap of knowledge for this component of the forest supply.

![Figure 1: Left – vessels has docked getting ready for loading. The small diggers are lined up to be lifted onboard and the bunks are full ready for the first heave. Right - typical large log-loader (17 tonne max.) delivering logs to ship, with on-board vessel crane in the background heaving bundles from the bunks onto the ship.](image)

C3 Ltd (www.c3.co.nz) is a leading logistics company that includes exporting logs from 15 ports around New Zealand and Australia. Tasman Bay Stevedoring provides stevedoring services at the Port of Nelson, which currently handles 7.2% of the NZ total log export volume. With support of both entities a time study evaluation was initiated to compare two different types of loader system configuration (4 loaders versus 2 loaders – operated by C3) servicing the four vessel cranes (operated by Tasman Bay Stevedores) analysing the types and lengths of delays associated with the two different loader configurations.

**Methods**

The study observed the loading of 26,500 m³ on to the ‘Rattana Naree,’ a bulk carrier vessel at Kingsford Quay, Port of Nelson. Data was recorded in four sessions on the 10th–12th of August, 2012, over 14.5 hours of FourLoader shift and 10.5 hours of day shift; totalling 25 hours – or 40% of the total loading time. A full time and motion study was carried out on both the loaders and on-board cranes to provide both a work rate as well as gaining an understanding of the delays on the overall system. A digital clock displaying to the nearest second was used to record measurements. Data was recorded in real-time using an excel spreadsheet. GPS units were used on all loaders to also track distance travelled. Time study readings were taken from a two-story high office which gave a clear view of loader activities around the loading area however there were visual limitations associated with tracking loader activities at log stacks located at the back of the storage areas. It was assumed that skill level, motivation, and ergonomic factors were the same for all loader operators and that delivery operations had no significant impacts from the weather conditions.
The loader fleet comprised of:
- ‘large’ loaders with 17 tonne (approx. 11-12 m³ log) capacity: Volvo L 22F (VO) and Kawasaki 95ZV (KA), (Figure 2),
- ‘medium’ loader with 15/16 tonne capacity, CAT 980G with ¾ grapple (C3q), and
- ‘small’ 14 tonne (approx. 7-8 m³) capacity loaders, CAT 980F (Cy) and CAT 966F (Cb).
The C3q loader only operated during the first session (1.5 hours) before being replaced by VO for the remainder of the study. Note that the tonne capacity is the maximum rated; the actual volume is typically considerably less when working with short log sorts.

![Figure 2 - Large Loaders used in both Shift Configurations](image)

Loading of vessels is organised into two shifts per day; a day shift (6am to 6pm) and a night shift (6pm to 6am). Teams work the shifts 24 hours per day until the vessel is fully loaded. For this study we were not able to vary the loader configuration during a shift. The vessel had four on-board cranes, and they are referenced by numbers 1 – 4 (starting at the bow). The two configurations were set as a block factor to assess and compare operational performances:
- **FourLoader** (Night shift): VO and Cy worked in tandem to load bunks 1&2 and KA and Cb worked in tandem to load bunks 3&4. One heave consisted of one ‘large’ load and one ‘small’ load.
- **TwoLoader** (Day Shift): VA and KA loaded bunks1&2 and bunks3&4 respectively. One heave consisted of one ‘large’ load.

For the loader, the cycle time was defined as the time it took for the loader to deliver a load to the bunks, with a new cycle beginning once the loader completed unloading the previous load. The heaving process for the cranes was defined as the load of logs being lifted from the bunks up onto the vessel for the diggers to then distribute, and then the empty strops being dropped back down to the bunks in preparation for the next heave. For both loaders and cranes delays were categorised into mechanical, operational, and social delays. Delays were recorded to the nearest second with delays over 30 seconds deemed significant. Mechanical delays are defined by machine mechanical unavailability. Social delays include both scheduled breaks and other personal breaks. Operational delays, which were the focus of the study, were defined as:

**Operations delays / Loader:**
1. **Waiting** in front of full bunk
2. **Machine congestion**
3. **Non-productive tasks**: e.g. preloading the berth, and adjusting or retrieving logs at the bunk.
4. **Management delay**: e.g. receiving instructions, foreman interaction
5. **All other** operational delays
Operations delays / Cranes:

1. **Bunk not full/ready**: including scanning delays and extended periods needed to strop up.
2. **Butting**: butting was completed using a loader with a large flat plate. It makes the fleeting process for the digger onboard the vessel easier.
3. **Digger Delays**: any crane delay caused by on-board diggers that stow the logs in the hold.
4. **Digger lifts**: all four diggers were lifted off the vessel in order to be serviced at the end of each shift, and lifted back on the vessel again ready for the next shift (Figure 4).
5. **Closing of the Hatches**: the hatches are closed so loading could continue on the deck of the vessel.
6. **Mark Off**: paint is used to identify parcels of wood, whereby the crane hoists a specific cage which was lifted onto the vessel (Figure 4).
7. **Management delay**: any delay where the crane had to stop its operations either for confirmation of instructions relating to the specific operation of the crane.

With respect to analysing the data, the operational delays were kept separate to the social delays as the primary focus of the study was based on operational delays during working time. Due to the nature of the study structure with capturing the start, middle and ends of the shifts at different times, it was deemed to be biased if social delays were also included.
Results

LOADERS

The average cycle time for the loaders was 3.0 minutes (Table 1). The FourLoader shift had a longer average cycle time of 3.2 minutes compared to 2.6 minutes for the TwoLoader shift.

<table>
<thead>
<tr>
<th>Loader</th>
<th>Shift</th>
<th>Configuration</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO</td>
<td>FOURLOADER</td>
<td>3.2</td>
<td>3.3</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Cy</td>
<td>FOURLOADER</td>
<td>3.2</td>
<td>3.4</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>C3q*</td>
<td>FOURLOADER</td>
<td>3.2</td>
<td>4.2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>KA</td>
<td>FOURLOADER</td>
<td>2.8</td>
<td>2.8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Cb</td>
<td>FOURLOADER</td>
<td>2.8</td>
<td>3.2</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>VO</td>
<td>TWOLOADER</td>
<td>2.6</td>
<td>2.7</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>KA</td>
<td>TWOLOADER</td>
<td>2.6</td>
<td>2.4</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: *C3q loader only operated during session one before being replaced by VO for the remainder of the study.

The GPS data showed a correlation between cycle time and distance to the log stack in the storage area, however the loader typically completed a circular track (one way loader movement to avoid the risk of incidents) and as such the correlation between distance and cycle time was not strong. The primary reason for the difference between the two configurations is the level of operational delay associated with operating four loaders.

The TwoLoader shift had a higher operational utilisation of 74.3% compared to 69.2% for the FourLoader shift (Table 2). During the FourLoader shift, the two large loaders, KA and VO, both had higher operational utilisations compared to the accompanying loaders, Cb and Cy. The utilisation of VO and KA were found to be similar during the TwoLoader shift.

<table>
<thead>
<tr>
<th>Loader</th>
<th>Bunk ID</th>
<th>Shift</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>Utilisation</td>
<td>Code</td>
<td>Utilisation</td>
</tr>
<tr>
<td>VO</td>
<td>80.0%</td>
<td>[1&amp;2]</td>
<td>74.4%</td>
</tr>
<tr>
<td>Cy</td>
<td>77.2%</td>
<td>[1&amp;2]</td>
<td>74.4%</td>
</tr>
<tr>
<td>KA</td>
<td>66.6%</td>
<td>[1&amp;2]</td>
<td>66.6%</td>
</tr>
<tr>
<td>Cb</td>
<td>57.0%</td>
<td>[1&amp;2]</td>
<td>57.0%</td>
</tr>
</tbody>
</table>

Note: *C3q loader only operated during session one before being replaced by VO for the remainder of the study.

Operational delays were significantly longer during the FourLoader shift, 29% greater than total percentage delay during the TwoLoader. A breakdown of the types of operational delays is
presented in Figure 5. No mechanical delays were observed over the study sessions. Loader C3q was omitted from delays analysis as this loader was only used during the first 1.5 hours of the study.

![Figure 5 - Operational Delays for Each loader for TwoLoader and FourLoader Shift Configurations](image)

The majority of operational delays came from being held up due the bunk being full. It can be seen that the distribution of operational delay types is very similar for both loaders (VA and KA) during the TwoLoader shift, however there is a noticeable difference in operational delays for loaders servicing bunks 1&2 compared to loaders servicing bunks 3&4 during the FourLoader shift. Cb and KA, which worked in tandem to fill bunks 3&4 had the longest amount of delays for the FourLoader shift. The high duration of non-productive task delays for Cb can be attributed to the role it had of being the designated ‘sweeper’, which is a work related task of associated with cleaning up the accumulated bark around the loading area.

**ON-BOARD CRANES**

The heave rate is defined as the number of completed crane cycles in an hour. Although this measure is a good indicator of efficiency, it does not consider the size of the heave. Table 3 shows the heave rates recorded for each crane, as well as the average, for the two loader configurations.

*Table 3: Heave Rates of the four cranes*
There is a distinct difference in heave rates, with the smaller average loads associated with the TwoLoader configuration being clearly faster. However, with both a large and small loader delivering logs to each bunk in the FourLoader configurations, larger volume heaves were made relative to TwoLoader. Each heave volume varies not just the number of deliveries to it, but also the length of log sorts will heavily influence total heave volume. Heave rates also varied by crane, for example the TwoLoader crane averages ranged from 7.9 heaves/hour to 10.9. This variation was also evident visually during the study as crane 4 had less delays from both onboard the vessel and from the butting procedures. Crane 2 had the lowest heave rate on the TwoLoader shift as there was a Mechanical Delay associated with a hydraulic hose failure with the diggers on the vessel. These heave rates were also evident in the utilisations (Table 4), being the percentage of productive time for the machine relative to the total shift time (excluding Social Delays).

### Table 4: Cranes Utilisation rates

<table>
<thead>
<tr>
<th>Utilisation Shift:</th>
<th>Crane #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>TwoLoader</td>
<td></td>
<td>85%</td>
<td>79%</td>
<td>96%</td>
<td>86%</td>
<td>86%</td>
</tr>
<tr>
<td>FourLoader</td>
<td></td>
<td>71%</td>
<td>75%</td>
<td>71%</td>
<td>69%</td>
<td>72%</td>
</tr>
<tr>
<td>Overall Total</td>
<td></td>
<td>76%</td>
<td>77%</td>
<td>80%</td>
<td>76%</td>
<td>77%</td>
</tr>
</tbody>
</table>

Consistent with the heaves rate results, there is a distinct drop in utilisation associated with the FourLoader shift associated. Crane 3 has the highest utilisation yet does not have the highest heave rate during the delay; this is due to an increased average cycle time.

Delays were broken down into several categories to obtain a better understanding of the types of delays that occurred during operation of both shifts (Figure 6). Delays were calculated by taking the total duration of each delay dividing by the actual working time (i.e. total study time minus social delay duration).
Digger lifts were the most significant delay occurring during the TwoLoader and this was due to the duration of each lift being over 4 minutes long. Butting and bunk delays are clearly higher for the FourLoader configuration. Along with a higher percentage of both butting and bunk delays occurring during the FourLoader shift, the duration of butting delays has also increased by approximately one minute on average. The demand for butting increased as the loader was needing to spend more time on each bunk due to the larger load being placed in the bunk relative to the TwoLoader shift load sizes. There was an attempt to minimise mark-off delays by completing the task within a social break. The high level of mechanical delay associated with the FourLoader occurred due to a failure of the generators on-board the vessel. During this time only one crane was able to operate.

**Discussion**

The shorter cycle times and less operational delays for the TwoLoader shift configuration suggest a more efficient alternative to FourLoader. The primary reason was the increase in operational delays that were found to be 29% larger during the FourLoader shift. It suggests excessive capacity for the four-loader configuration. Including heave size as a factor into future studies would allow a full productivity comparison.

This study does have limitations in accurately estimating long-term trends and large delays are not adequately sampled. The study assumes that the effects on cycle time and delays are associated with different loader configurations. However, the true and full effect of TwoLoader / FourLoader on basic operations is not known. The ship vessel was loaded primarily over the weekend. The increased interaction with log trucks that need to be unloaded can be expected to affect delays during the normal work week days. The range of loading conditions is also limited due to the short duration of the study. Variation associated with unmeasured effects could have an impact on
quantifying average cycle times and delay analysis. For example, it was noted that wet weather conditions are likely to have an impact on the loading.

The two configuration compared not only changed the number of loader from four to two, but also the way the bunks were loaded. Going from putting two scoops (one large, one small) into a bunk to just one large scoop simplified the operation resulting in both lower loader cycle time and faster heave rates. However, there were other benefits noted, including that more extensive butting was required and that scanning became more problematic with the fuller bunks. Such issues could also be compounded, for example at times two or more cranes would become synchronised with their cycles, meaning that butting would be required on several bunks at once. This would result increased delays in waiting for the loader to butt up a bunk. A replicate study that also recorded the actual heave volume would establish actual productivity difference.

Using the data as well as visual observations, an opportunity for improvement was also identified in the operational procedures of the diggers. The Diggers were lifted on to the vessel at the start of each shift and lifted off at the end. Although diggers due need to be lifted off occasionally, for example so that the hatches can be shut and the need to refuel, consideration could be given to lowering just the personnel without the digger.

**Conclusion**

Improving port capacity and capability for servicing the log export business will be critical for New Zealand to successfully accommodate the expected increases. With ports typically very spatially constrained, the initial focus is on improving current delivery systems. After completing a total of 25 hours of elemental time study on the Rattana Naree between the 10th-12th of August 2012, a simple conclusion can be made that the current shift structure containing four loaders incurs more operational delays for both the loaders and the on-board cranes. The most common type of delay was butting and bunk delays.

**References**


