A Log Delivery Case Study at the Port of Nelson

PORT NELSON
The Region's Gateway to the World

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Executive Summary

A detailed time and motion study and GPS study was completed at the Port of Nelson on the loaders during the loading of the Rattana Naree vessel on the 10th – 12th of August 2012. The study focussed on cycle times and delays to assess the impact of the loader configurations on loader delays. A parallel study was done by fellow undergraduate forest engineer, Mr D. Hopper, who evaluated the impact of the two loader configurations on crane delays.

The current log delivery configuration of four-loaders was compared to a two-loader configuration which ran during the night shift and day shift respectively. Delays were categorised into operational, mechanical, and social delays. No mechanical delays were recorded and social delays were omitted from operational delay analysis due to the sample session times which overestimated the amount of smoko delays.

The average loader cycle time during the night shift was 3.2 minutes and the average cycle time during the day shift was 2.6 minutes. The main factor for differences in cycle times was attributed to the travelled distance for each cycle. However loader cycle time and travel distance are not strongly correlated as loaders tended to have a circular route when picking up loads. The operational utilisation rate for the night shift and day shift was 69.2% and 74.3% respectively. The operational delays for the night and day shift totalled 32.3% and 25.1% of the loaders productive time respectively, a 29% increase with the majority of the delays coming from the bunks being full.

Overall for the loader part of the operation, a conclusion can be made that the two-loader configuration was a more efficient option that had no adverse impacts on crane delays. However loader productivities and costs need to be determined in order to verify which configuration was the most productive.

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INTRODUCTION

OVERVIEW

As demand for export logs in New Zealand continue to increase there are significant opportunities to increase export earnings [1]. In order to capitalise on the increasing demand, on-port operations will need to increase infrastructure or improve existing operations through innovative solutions. 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. This case study assesses this option; focussing on log delivery operations, an integral component of vessel loading operations.

Log delivery is a port operation during vessel loading that delivers logs from on-port storage to the stevedores. While it is important for this service to have sufficient capacity that ensures no adverse impacts on productivity to stevedore operations, there is uncertainty on what the most efficient and cost-effective loading configuration is for loaders when delivering logs to the crane loading area (bunks). With no published studies found on log delivery operations in terms of operational performance and productivity, this study seeks to fill the gap of knowledge for this component of the forest supply chain.

SITE AND LOG DELIVERY OPERATION

Two log delivery options at the Port of Nelson were evaluated. C3, a leading business in product handling that handles 7.2% of New Zealand's total export logs through the Nelson Port [1] provide this marshalling service. The current delivery configuration is to have four loaders deliver logs to four bunks; where the vessel is loaded by the stevedores. This configuration potentially has excessive capacity and thus a low utilisation. Consideration is being given to reduce the number of loaders to achieve a more cost effective log delivery option. To provide some quantitative information on utilisation, an independent comparison between the four-loader configuration and a two-loader configuration was conducted through a time and motion study and GPS study.

The focus of this study was to identify the impact of the loader alternatives on the loader delays. A parallel study was done by fellow undergraduate forest engineer, Mr David Hopper, who evaluated the impact of the two loader configurations on crane delays. It is hoped the study will also provide a bench-mark in log delivery operation configurations and will contribute towards seeing the New Zealand export log industry's ability to cater for, and capitalise on the increase in export log demand.

METHODS

A detailed time and motions study was conducted. GPS units were also placed in the loaders for the duration of the study to capture loader movement and distance travelled. Methods for both sections are detailed below.

TIME STUDY

A full time and motion study was carried out on the loaders to provide a basic breakdown of tasks for the duration of the loading as well as gaining an understanding of the delays on the overall system. This method was chosen as it is an effective method in comparing the delay-free production and documenting small delays (>10min) between alternative configurations compared to point-sample time studies and shift-level methods [2]. The time study focussed primarily on cycle times and delays. A digital clock displaying to the nearest second [hr:min:sec] was used to record measurements in real-time formatting to the accuracy of one minute and excel was used to electronically record the data.

The loader fleet comprised of two 'large' loaders, VO and KA, (Figure 1), one 'medium' loader, C3q, and two 'small' Cats, Cy and Cb (Table 1). The C3q loader only operated during the first session (1.5 hours) before being replaced by VO for the remainder of the study. See appendix A.1 for details on which loaders were operating during each shift observed.

TABLE 1 - SPECIFICATIONS FOR LOADERS OPERATING DURING STUDY SESSIONS

Loader	Abbreviation Code	Maximum* (tonnes)
Volvo L 220F	**VO**	17
Kawasaki 95ZV	**KA**	17
Cat 980G (3/4 bucket)	***C3q***	*15/16*
Cat 980F	**Cy**	14
Cat 966F	**Cb**	14

*NB. Approximate maximum - less if working with short logs.

FIGURE 1 - LARGE LOADERS USED IN BOTH SHIFT CONFIGURATIONS

The two configurations were set as a block factor to assess and compare operational performances represented by their corresponding shift of 'Night' and 'Day' respectively. A BunkID of 1&2 or 3&4 was assigned to each loader according to which bunk pair it was servicing to provide further detail on loader performance. The description of the two loader configurations is listed below:

- **Night shift (1800-0600):** The current loading option which consists of four loaders to deliver log loads to the bunks. 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.

- **Day Shift (0600-1800):** Comprised of the two large loaders, VA and KA, which loaded bunks1&2 and bunks3&4 respectively. One heave consisted of one 'large' load.

A 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. Cycle times were recorded separately to delays in order to get non-delay cycle times and cycle rates. Delays associated with the loaders were categorised into mechanical, operational, and social delays (Table 2). Delays were recorded to the nearest second with delays over 30 seconds deemed significant.

TABLE 2 - DELAY CATEGORIES ASSOCIATED WITH LOG DELIVERY OPERATIONS

ASSOCIATED DELAYS		
Mechanical Delays	**M1**	Mechanical unavailability of loader
Operational Delays	**O1**	Waiting in front of full bunk
	O2	Any delays associated with machine congestion
	O3	Non productive tasks: The most common non-productive tasks included 'preloading the berth'*, and adjusting or retrieving logs at the bunk.
	O4	Management delay: receiving instructions, foreman interaction etc
	O9	All other operational delays
Social Delays	**S1**	Smoko / scheduled break
	S2	Any other 'social' delay: drinks, toilet break, talk etc.
Other Delays	**X1**	Any delay not fitting into above categories

**Shifting logs closer to the loading area while waiting for bunks for empty.*

Social delays were biased with the number of smoko delays covered in the sessions being an inaccurate representation for the study duration. The session time structure consequently overestimated percentage of social delays for each loader. Loader utilisation, operational and mechanical delays were thus analysed with social delay times omitted.

STUDY STRUCTURE

The study observed the loading of the *'Rattana Naree,'* a bulk carrier vessel (Figure 2, right image) at Kingsford Quay, Port of Nelson. It was infeasible to record the entire loading time of the 24hour/day operation with the available resources and personal. Sample data was recorded in four sessions on the 10^{th}–12^{th} of August, 2012, over 14.5 hours of night shift and 10.5 hours of day shift; totalling 25 hours (see appendix A1 for a breakdown of session times and duration). The sessions covered 40% of the total loading time of the vessel and gave a reasonable representative of loader operations during vessel loading as the sessions were strategically placed to cover the various stages of the shift (start, middle, and end). The proportion of night and day shift allowed appropriate comparisons between each loader configuration.

Time study readings were done from a two-story high office located to the east side of Kingsford Quay. This site 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.

FIGURE 2 - VIEW OF PORT OPERATIONS (RIGHT IMAGE) FROM THE OFFICE USED FOR THE STUDY (LEFT IMAGE)

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.

GPS STUDY

GPS technology was used to track loader movements during loading operations to find basic distance and time information. Handheld GPS units were set to point-measurements every five seconds and secured onto the back window of the loaders to track movements during loading operations. The GPS study followed the same study structure as the explained in the previous section. GPS conversion software was used to analyse data for the loaders. Data captured over approximately 3 hours during the 11th August night shift and 2.5 hours during the 11th August day shift was used to represent loader movements.

Through programming in excel, cycle times were automatically estimated from the GPS data based on the movement of the loader from a 'fenced' area. This 'fenced' area included the loading area along the length of the wharf encompassing all four bunks. As such the GPS study cycle times reflect the time the loader is moving around the yard, but does not include the time near the bunk. It is an automated and quick way to identify loader cycles, and also allows us to relate cycle time to distance travelled, but is not as accurate as the time and motion study described above. With regard to the raw data, identified social delays were removed by filtering cycle times that were >10 minutes to remain consistent with the time study method. Generated cycles were filtered to cycles that were >1 minute to remove 'false' shorter cycles that occurred due to the time the loader was preloading the berth and adjusting or retrieving logs at the bunk which was falsely counted as cycles by the GPS conversion software. This overestimated cycle rates and underestimated cycle times.

RESULTS

CYCLE TIMES AND RATES

The average cycle time results for the loaders are presented in Table 3.

TABLE 3- LOG DELIVERY CYCLE TIMES (MINUTES)

Loader				Bunk ID		Shift		Total
Code	Average	Min	Max	Code	Average	Code	Average	Average
VO	**3.3**	*1*	*9*	[1&2]	**3.4**	NIGHT	**3.2**	**3.0**
Cy	**3.4**	*1*	*7*					
C3q*	**4.2**	*2*	*6*					
KA	**2.8**	*0*	*8*	[3&4]	**2.9**			
Cb	**3.2**	*1*	*8*					
VO	**2.7**	*1*	*7*	[1&2]	**2.7**	DAY	**2.6**	
KA	**2.4**	*0*	*5*	[3&4]	**2.4**			

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

The average cycle time for the loaders was found to be 3.0 minutes. The night shift had a longer average cycle time of 3.2 minutes compared to 2.6 minutes for the day shift (Table 3). Loaders servicing bunks 1&2 had longer cycle times than bunks 3&4 for the day and night shift.

Cycle rates were found per Scheduled Machine Hours (SMH) and Productive Machine Hours (PMH) and presented in Table 4.

TABLE 4 - CYCLE RATES PER SMH AND PMH

Loader			Shift		
Code	Cycle/SMH	Cycle/PMH	Code	Cycle/SMH	Cycle/PMH
VO	12.7	18.2	Night	12.1	18.9
Cy	12.2	17.5			
KA	13.6	21.7			
Cb	9.9	18.8			
KA	17.8	24.7	Day	17.0	23.5
VO	16.1	22.2			

The day shift rate was found to be 23.5 cycles/PMH and 17.0 cyles/SMH compared to 18.9 cycles/PMH and 12.1 cycles/SMH for the night shift. Results in SMH omit social delay times and are thus larger than actual rates if the social delays were included. Cb had the lowest cycle rate for the night shift while KA had the highest cycle rates for both the night and day shift.

OPERATIONAL UTILISATION

The day shift had a higher operational utilisation of 74.3% compared to 69.2% for the night shift (Table 5). During the night 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 day shift.

TABLE 5 - OPERATIONAL UTILISATION OF LOADERS (EXCLUDING SOCIAL DELAYS)

Loader		Bunk ID		Shift		Total
Code	Utilisation	Code	Utilisation	Code	Utilisation	Utilisation
VO	**80.0%**	[1&2]	**76.8%**	NIGHT	**69.2%**	**<u>70.5%</u>**
Cy	**77.2%**					
C3q*	**50.6%**					
KA	**66.6%**	[3&4]	**61.8%**			
Cb	**57.0%**					
VO	**74.4%**	[1&2]	**74.4%**	DAY	**74.3%**	
KA	**74.2%**	[3&4]	**74.2%**			

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

DELAY ANALYSIS – OPERATIONAL AND MECHANICAL

Total operational delays for loaders during the day and night shift are presented in Table 6.

TABLE 6 - LOADER PERCENTAGE OPERATIONAL DELAYS FOR BOTH CONFIGURATIONS

Loader	Night	Day
VO	*17.5%*	*25.1%*
KA	*31.5%*	*25.1%*
Cy	*20.7%*	*N/A*
Cb	*39.8%*	*N/A*
C3q	*68.3%*	*N/A*
ALL	**32.3%**	**25.1%**

Operational delays were significantly longer during the night with the total percentage delays found to be 32.3% which was 29% more than total percentage delay during the day shift of 25.1%. VO and KA had the same percentage delay during the day however; during the night KA nearly had almost double the percentage delay of VO (Table 6, VO and KA values).

A breakdown of the types of operational delays is presented in Figure 3 to give a visual comparison between each loader, bunkID, and shift configuration. 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 which gave an extreme operational percentage delay (Table 6, C3q) that disproportionally affected visual analysis.

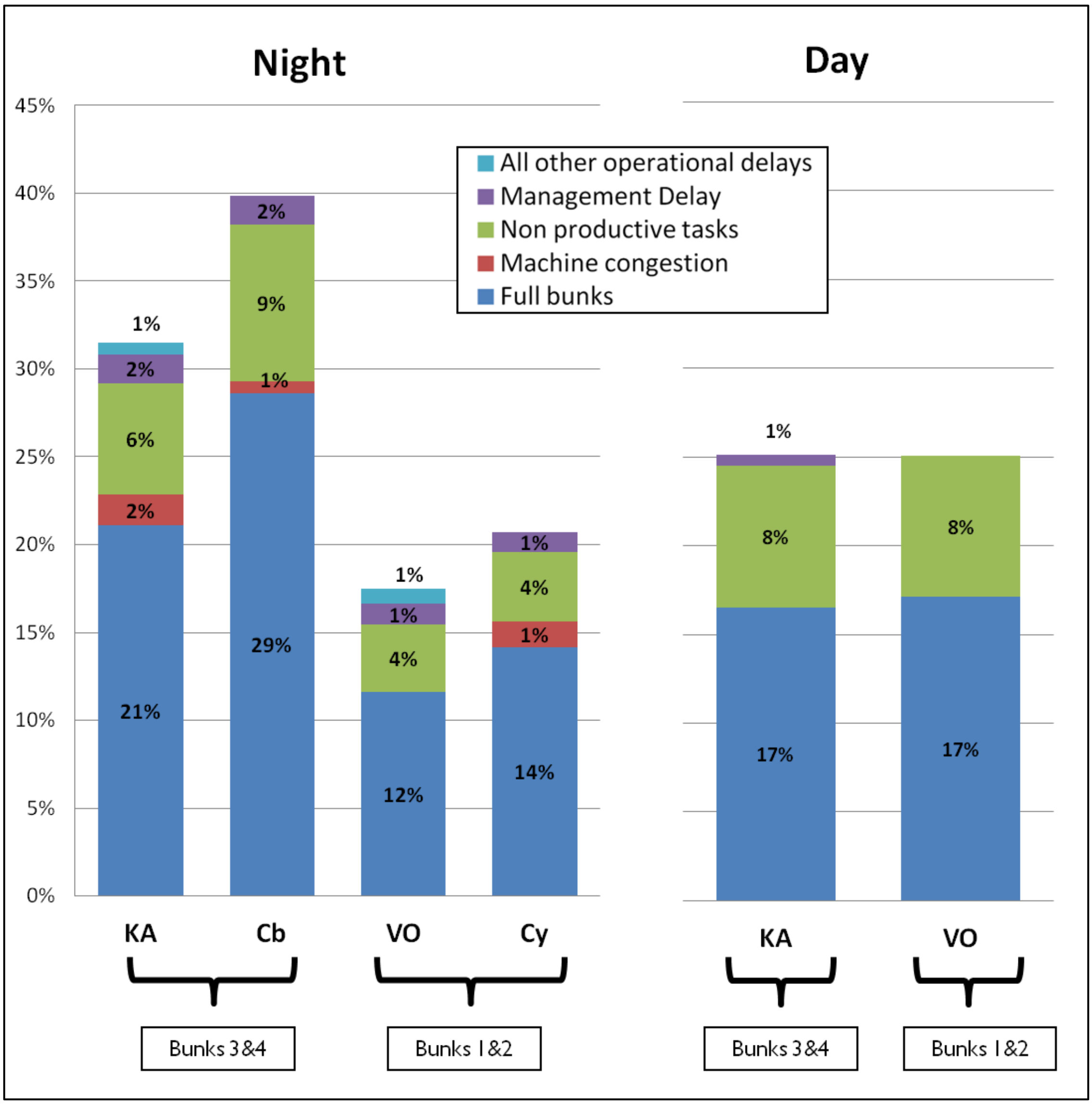

FIGURE 3 - OPERATIONAL DELAYS FOR EACH LOADER FOR DAY AND NIGHT SHIFT CONFIGURATIONS

The majority of operational delays came from being held up due the target bunk being full (Figure 3, 'Full bunks'). It can be seen that the distribution of operational delay types is very similar for both loaders (VA and KA) during the day 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 night shift. Cb and KA, which worked in tandem to fill bunks 3&4 had the longest amount of delays for the night shift (Figure 3). The high duration of non-productive task delays for Cb can be attributed to the role it had of being the designated 'sweeper' (see appendix A.2 for individual breakdowns of operational delays for each loader).

Types of operational delay for day and night shift are presented in Figure 4 below.

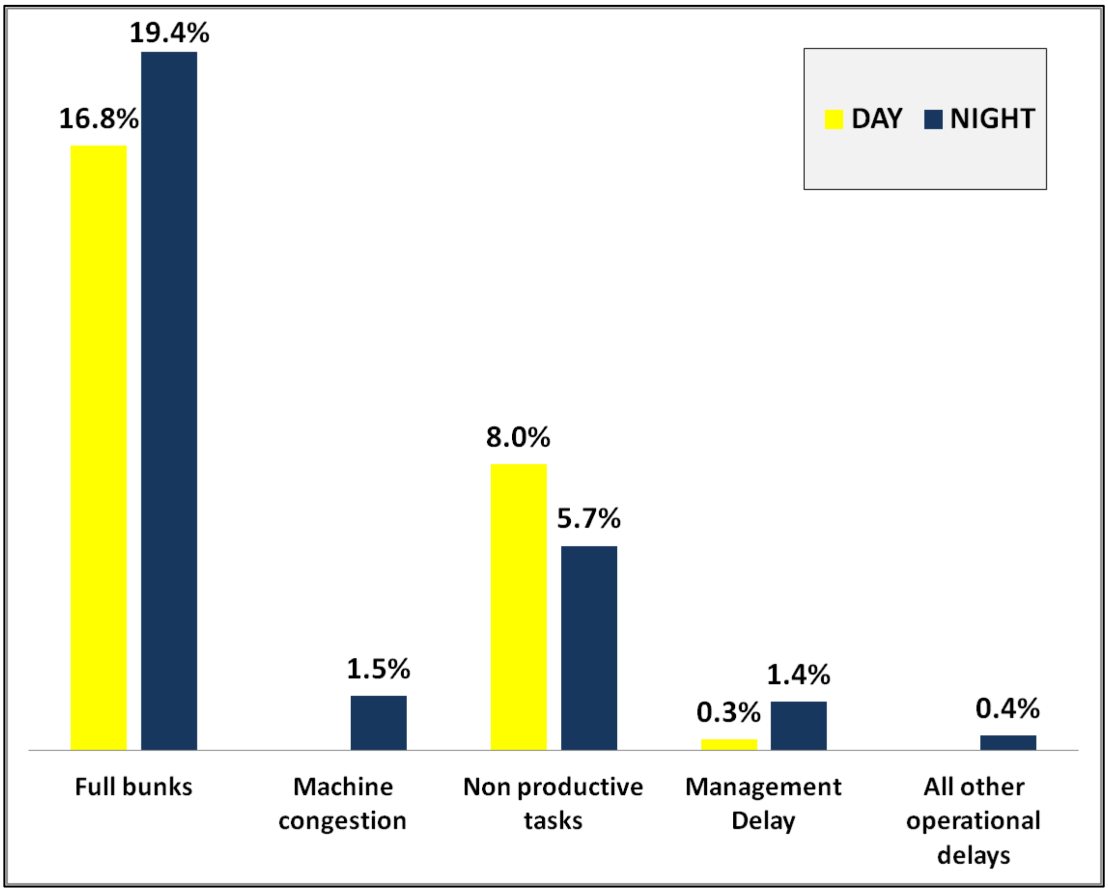

FIGURE 4 – TYPES OF OPERATION DELAYS DAY AND NIGHT SHIFT CONFIGURATIONS

The delay stemming from bunks being full was 15% larger during the night shift. Machine congestion only occurred during night shifts due to the loaders waiting for their paired loader to finish cycle load. Non-productive task delays were 40% greater during the day. It was observed during the study that preloading the berth occurred significantly more during the day while bunks were full, which could explain why there was an increase in non-productive task delays and a subsequent decrease in full bunks delays.

DELAY ANALYSIS – SOCIAL

The average smoko and shift turn-around times are presented in Table 7.

TABLE 7 – AVERAGE SOCIAL DELAYS (MINUTES)

	Shift Change	Smoko
Day	20.7	29.3
Night	21.0	29.5
Total	**20.9**	**29.5**

The average smoko break was 29.5 minutes for the loaders which was significantly less than that of the stevedores observed by Mr. David Hopper to be approximately 38 minutes [3].

GPS TRACKING

The GPS distance and time results are presented in Table 8.

TABLE 8 –AVERAGE CYCLE TIME AND DISTANCE FOR LOADERS DURING DELIVERY OPERATIONS

Loader				Shift			
Code	Cycle/SMH	Distance (m)	Ave. Speed (km/hr)	Code	Cycle/SMH	Distance (m)	Ave. Speed (km/hr)
VO	11.5	724.4	8.3	Night	11.9	644.3	7.4
Cy	10.8	726.6	7.8				
KA	12.7	571.4	7.3				
Cb	11.2	575.3	6.4				
VO	13.0	511.2	6.6	Day	14.2	384.2	5.3
KA	15.1	284.0	4.3				

The number of cycles per SMH was found to be 11.9 for the night shift. The day shift produced 14.2 cycles per SMH, a 2.3 cycle/SMH increase. VO and Cy had significantly higher average distance/cycles compared to KA and Cb which was due to the location of the log stack differences whilst loading their respective BunkID.

DISCUSSION

Operational delays that were found to be 29% larger during the night shift suggest excessive capacity for the four-loader configuration. The shorter cycle times and less operational delays for the day shift configuration suggest a more efficient alternative - a productivity case-study would verify this. The case study done by Mr D. Hopper found no significant adverse impacts to crane operations using the two-large-loader configurations. In fact, crane delays were significantly less during the day for loader related delays [3]. The study assumes that the effects on cycle time and delays are associated with different loader configurations, whereby the night shift had four loaders and the day shift two. The effect of day / night on basic operations is not known. Another aspect of this particular study is that the ship was loaded primarily over the weekend. Increased interaction with, and or diversion to unload, log trucks can be expected to affect delays.

This study does have limitations in accurately estimating long-term trends and large delays are not adequately sampled [2]. The range of loading conditions is also limited due to the short duration of the study. In order to gain a reasonable representative sample with unbiased social delays, session times should be strategically placed to cover scheduled smoko and social breaks proportional to operational time observed. If possible, capturing the entire loading time of a vessel would be the most ideal scenario. The office location where the study was conducted had visual limitations whilst tracking the whereabouts of the loaders outside of the loading area. Delays associated near log stacks may be inaccurately measured. A more elevated site that had a better bird's eye view would enable easier tracking of loader movements.

Variation associated with randomly measured variables, unmeasured conditions, and delays would have an impact on quantifying average cycle times and delay analysis. For example, it was recorded through visual observations that wet weather conditions may have an impact on the loading and unloading elements of delivery operations but the extent of the impact was not measurable in terms of cycles per hour. Random occurrences of delays may also cause a sampling error (estimated percentage delays may differ if the study is replicated). These sources of variation and stated assumptions require isolation in order to discriminate true differences that may be occurring.

By looking at the results from the time and motion study and GPS study, the main factor for differences in cycle times was attributed to the distance travelled for each cycle. Loaders that had longer cycle times generally had to travel further to log stacks and vice versa. This observation also held true when comparing the cycle time and corresponding distances travelled per shift.

Cycles rates per SMH were slightly larger for the GPS study (Table 8) than that found from the time study analysis (Table 4). This could be due to non-productive activities such as preloading the berth, sweeping, and log adjusting or retrieving at the bunk being wrongly counted as productive cycles in the GPS conversion software. The accuracy of the GPS analysis could be increased by reducing the point-measurements to >5 seconds as it was noted that loaders reached speeds >60km/hr.

CONCLUSION

From the results of the detailed time and motion study and GPS study done on the loading of the Rattana Naree vessel, the conclusion can be made that the two loader configuration was the more efficient log delivery option with operational delays being 29% larger in the night shift. Non-delay-cycle times for the loaders were a function of the distance travelled from the log stacks to the bunks and the time taken to unload into the bunks. Determining the productivity and cost of the loaders during log delivery operations would verify which configuration is more efficient and cost effective.

REFERENCES

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3. D, H. (2012). *An elemental time study on the cranes of the Rattana Naree.* Christchurch: University of Canterbury.

APPENDIX

A.1

Configuration code:

Session	Duration	Night Shift (hrs)	Configuration	Day Shift (hrs)	Configuration
1	2230-0000	1.5	KA/C3q/Cb/Cy	-	-
2	0300-1000	3	KA/VO/Cb/Cy	4	KA/VO
3	1500-2200	4	KA/VO/Cb/Cy	3	KA/VO
4	1430-0000	6	KA/VO/Cb/Cy	3.5	KA/VO
	Total	**14.5**	**Total**	**10.5**	

KA ➔ Kawasaki 95ZV
VO ➔ Volvo L 220F
C3q ➔ Cat 980G (3/4 bucket)
Cy ➔ Cat 980F
Cb ➔ Cat 966F

A.2

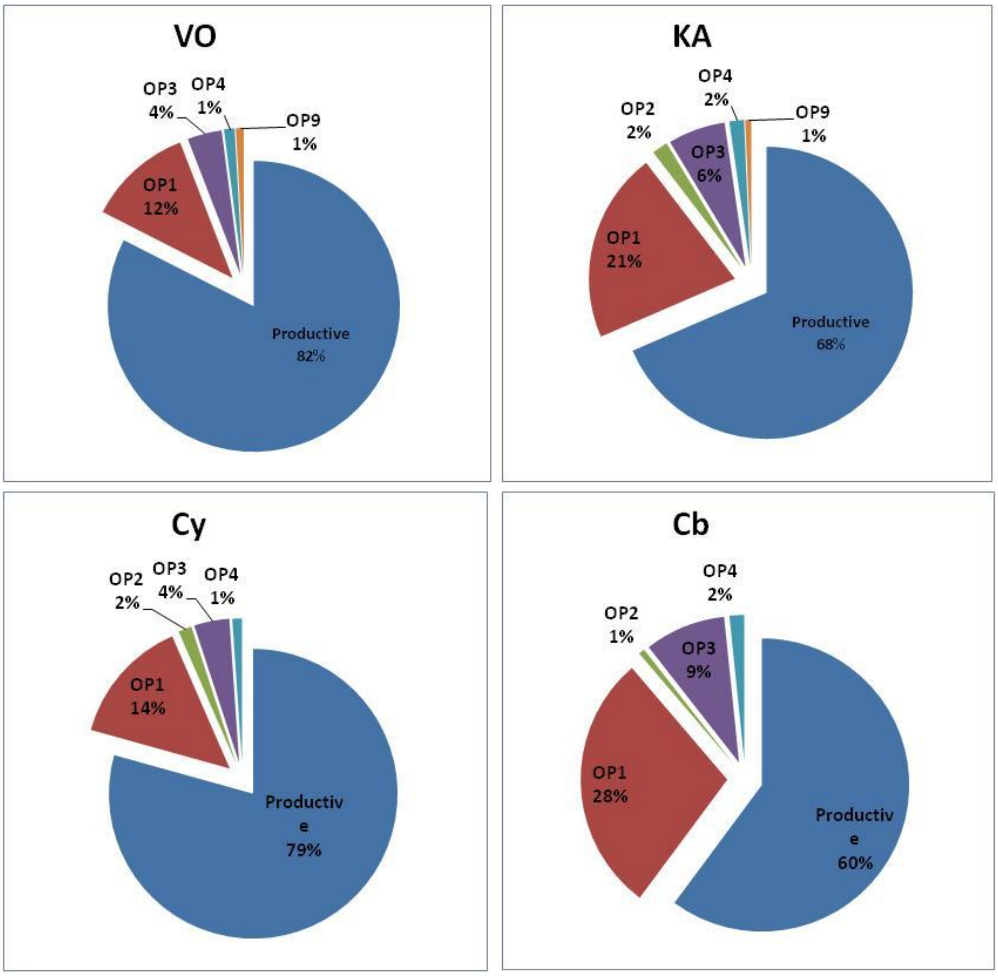

FIGURE A2.1 – OPERATIONAL DELAY OF LOADERS DURING NIGHT SHIFT

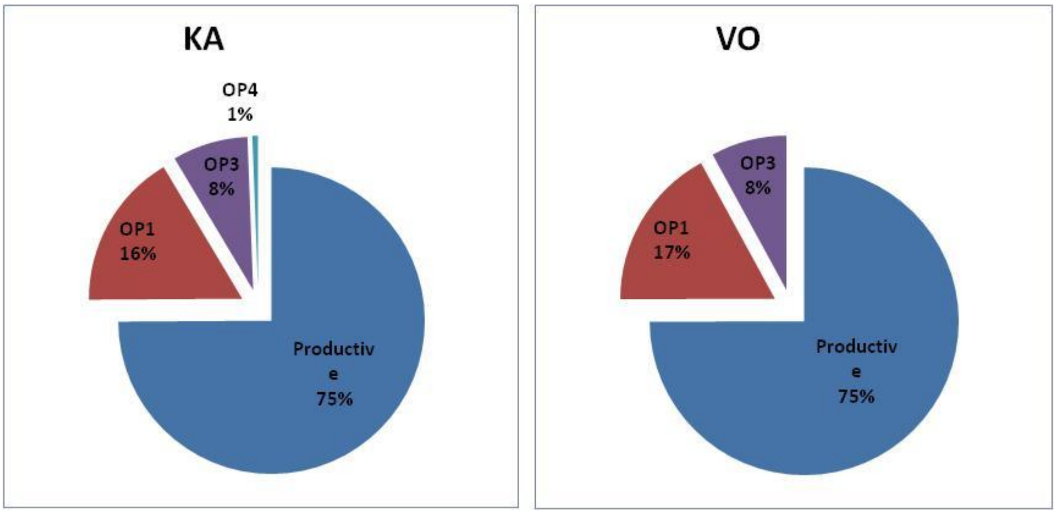

FIGURE A2.2 – OPERATIONAL DELAY OF LOADERS DURING DAY SHIFT