# Optimising log storage and handling in New Zealand ports

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Moving logs to shipside

## Abstract

Forestry is one of New Zealand's largest export sectors for both value and volume. Logs are exported from all but one of the ports in this country. An increase in log volume exports is likely over the next decade, which will put added pressure on port-handling facilities and increase the need for productivity improvements and optimisation of storage.

A multi-objective log storage and handling model was developed after visiting seven New Zealand ports. The objective function includes three key parameters: storage capacity, overall handling costs, and row-to-shipside handling times. The model was validated and verified by using it to determine potential improvements in storage capacity at New Zealand's three largest log export ports. It can be applied to greenfield log storage operations as well as brownfield.

The model development, along with demonstration of the impacts of selected changes to log supply, equipment and log storage area characteristics, are described. Potential gains in storage capacity ranging from –2% to +98% are indicated.

## Introduction

Port efficiency is an important determinant of shipping costs (Sanchez et al., 2003; Clark, Dollar & Micco, 2004). Port customers (shipping lines, cargo owners and agents, and suppliers of services) evaluate the performance of ports in different ways, although there is considerable overlap in evaluation criteria (Brooks et al., 2011). Criteria relate to both effectiveness (e.g. provision of accurate and timely information, cargo security and lack of damage) and efficiency (e.g. timely vessel turnaround, low costs) (Brooks & Schellink, 2013). De Monie (1987) comments that evaluating a port's performance cannot be based on a single value or measure, rather sets of measures relating to the different players in the supply chain are required.

A little over 7% of global industrial roundwood production (~128 million tonnes) is exported annually in log form (FAO, 2015). Forestry is New Zealand's third largest export earner by value (Statistics NZ, 2015) and the largest exporter by volume. In 2013, New Zealand was the world's largest exporter of softwood logs, exporting 57% of the log volume harvested from its man-made plantations. Logs are currently exported in bulk form from all but one of this country's 13 maritime ports; containerised logs are exported from the remaining port. By way of comparison with two other large timber-producing regions from the Pacific Rim region, 19% of the volume harvested from Oregon and Washington forests in 2010 was exported as logs (Warren, 2011) and less than 1% of the volume harvested from Chile was exported as logs (FAO, 2015).

The New Zealand government has set a goal of doubling export earnings from all products by 2025 (MBIE, 2012). An increase of 60% in export log volumes may be required by 2025 unless more log processing and adding value takes place within New Zealand. This will put added pressure on port-handling facilities and increase the need for productivity improvements and for optimisation of storage. Logs compete with other export products for storage space at many ports. The efficient use of storage capacity and log-handling equipment at New Zealand ports is, and will continue to be, of considerable interest to this country's forest sector, port authorities and shipping lines.

This paper describes the development and application of a model to optimise the storage and handling of logs to shipside in New Zealand ports. Stevedoring functions related to counting, tracking and moving logs from shipside to on-ship are not included in the model.

## Brief literature review

A review of the literature found much research that was related to the storage and handling of containers at ports (e.g. Kozan, 1997; Sgouridis, Makris & Angelides, 2003; Lee et al., 2008; Ping, 2011), but very little information that was specific to optimising the storage and handling of logs at ports. Takel (1983) provided a simplified, mathematical approach for determining non-cargo-specific storage requirements that considered factors such as the bearing strength of the site, the height to which stacking can take place, and the type and productivity of equipment used for handling cargo on the wharf. Munisamy (2010) modelled handling of sawn timber in a timber terminal at Port Klang, Malaysia and demonstrated how queuing theory could be used to improve handling efficiency and throughput capacity. Storage of sawn timber at the terminal was not considered.

The literature review also highlighted the absence of a model for optimising the storage and handling of logs at ports. It underscored the need for such features as auto-generation of potential layouts, flexibility in determining block sizes and orientation, site characteristics, log size distributions, simultaneous consideration of storage and handling, and the use of multiple criteria for evaluating solutions.

## Log storage and handling operations

Log storage and handling operations managed by C3 Ltd (C3) at seven ports around New Zealand were visited over a two month period in mid-2014. C3 is this country's largest on-wharf logistics provider and they operate in 14 ports and five inland sites in New Zealand and Australia. They provide marshalling, stevedoring, warehousing and wharf cartage for a wide range of cargo types. C3 currently count, measure, handle and track over 40 million logs exported per year.

The seven ports visited were Northport (Marsden Point), Port of Tauranga, Eastland Port (Gisborne), Napier Port, Port Marlborough (Picton), Port Lyttelton and Port Otago (Port Chalmers). The first four named ports are New Zealand's largest log-handling ports. The field visits provided opportunities to discuss storage and handling issues with local C3 managers, to view existing layouts of C3's allotted storage areas, and to assess the range of log-handling equipment available. This was done to determine work flows, and to find out what data was already being captured that might be of use in constructing a model to optimise log storage and handling.

Most logs arrive at a port by truck, some by rail, some by barge, and some by a combination of these modes of transport. As many as 10 customers can be supplying logs to a port. Log lengths vary from under 3 m to over 12 m and come in a range of sizes and grades. Logs of a given length, size, grade and customer are kept in separate rows. Log characteristics affect storage capacity and handling productivity. All logs are measured and tagged. For some ports, measuring and tagging takes place on arrival at the port. For other ports, it takes place prior to arrival.

If the logs arrive by truck, it is directed to a numbered row and then the logs are unloaded from the truck and stacked in the storage row. If logs arrive by rail, they are unloaded and then moved to a numbered storage row. If logs arrive by barge, they are first unloaded from the barge then moved to an area where they are tagged and measured, and from there they are moved to a numbered storage row. Unloading and movement to storage rows can be undertaken with equipment that ranges from large tricycle-steer wheeled logstackers (e.g. Wagner L100) to small pivot-steer wheeled loaders fitted with log grapples (e.g. Volvo 150).

Logs can be stacked to the height of the eye-level of the machine operator. The surface of some port storage areas may be sealed. Some storage areas have unsealed surfaces, which necessitate lower stacking heights for row stability reasons. Most ports have stanchions, also called 'book-ends', available to improve storage capacity and safety near boundaries. Up to two book-ends can be used for mid-length and long logs, but only one can be used on short logs. Few ports have a book-end available for every row. In some ports high-stackers fitted with log grapples, also known as material handlers, are used to stack logs to greater heights, thereby increasing row heights and storage capacity. Gaps are left between rows to facilitate log volume stocktaking after vessel loading of partially out-loaded rows.

For biosecurity reasons, most logs leaving New Zealand's shores are fumigated either in the cargo hold en route overseas or onshore if the logs are to be stored above deck. Onshore fumigation is carried out at three ports. Gaps are left between rows to facilitate fumigation, which normally takes 24 hours. While fumigation is being carried out no log-handling activity can take place on either side of the row being fumigated. Fumigation cannot take place on unsealed surfaces and currently limits the maximum row height to 6 m.

Port of Tauranga

When a log vessel arrives the logs are moved direct to shipside or to a preloading area at berthside. A preloading area is only utilised at Tauranga where log storage is spread over a wide area. A range of equipment is used to move the logs from rows to shipside or berthside. These include tricycle-steer log stackers, pivot-steer wheeled loaders, conventional trucks, shuttle trucks (with larger payloads than conventional trucks) and terminal trucks with detachable trailers. If logs are first moved to the preloading area at berthside by truck, they will be unloaded with log stackers or pivot-steered wheeled loaders. Logs are moved from berthside to shipside by log stackers or pivot-steered wheeled loaders.

Logs arriving at shipside by log stackers or pivot-steered wheeled loaders are placed into cradles. A count of the logs is then made and their tags may be electronically recorded. Wire slings are then wrapped around the logs and they are loaded in the ship's hold. Logs arriving at shipside by truck may be directly loaded into the hold after being counted and having their tags electronically recorded.

## Method

### Model development

A draft version of a log storage and handling model called OPTILOGS (Optimum Log Storage) was developed in Visual Basic 2013. The model spans activities from arrival at the port to loading into the cradle or ship's hold, but excludes log measurement and tagging. OPTILOGS is a tactical planning model as it operates at a block level, not at an individual row level. A block contains a number of rows; the number depends on the length of logs being stored in the block.

Base data used within OPTILOGS was gathered from a range of sources. Data on packing density factors, i.e. the solid wood volume stacked within one cubic metre of air space, for a range of log types were obtained from C3's log storage database. Data on safe stacking heights were obtained from equipment brochures and C3 personnel. Data on hourly machine costs were based on leasing costs and discussions with C3 personnel. Data on handling machine load sizes for a range of logs sizes were gathered through field observation and discussions with C3 personnel. Data used in developing time consumption equations for a range of log-handling equipment were gathered by fitting GPS-enabled digital cameras to equipment at three ports within New Zealand. Regression analysis was then used to build the time consumption equations.

Model verification and validation were carried out with the assistance of C3 branch managers and senior managers before it was applied in three case studies. These were used to demonstrate its utility and to identify existing efficiency and potential improvements in storage capacity and log-handling at C3's operations.

## Model description

OPTILOGS automatically generates 3D layouts for specified areas using standard facilities layout patterns (serpentine block structure) for relatively simple areas. 3D layouts allow the inclusion of row height characteristics as well as location in the optimisation procedures. It uses a full search optimisation procedure to identify the best layouts based on three criteria (storage capacity, handling costs and row-to-shipside time) or a combination of these. Weightings to the criteria are set by the user.

Ports are split into log storage areas, and each area is described with seven features and five inter-activity distances. The area features are length, width, surface type, surface camber direction, whether fumigation is allowed or not, if the area is common storage or has been allocated to a specific customer, and whether specific machines have to be used in the area. The interactivity distances are area-to-shipside, area-to-berthside, area-to-scale (= measurement) shed, area-to-rail and area-to-barge scaling point. Three additional interactivity distances are also required; berthside unloading point to berthside area, berthside-to-shipside, and barge-to-barge scaling point.

OPTILOGS will choose, from the equipment selected by the user, the combination of log-handling equipment that best suits an area unless specific equipment has been allocated to the area. Specific equipment may be allocated, for example, when one log storage area is located a considerable distance from the other such areas.

Data inputs to, and user interactions with, the main OPTILOGS optimiser form include:

- The percentage of log volume arriving by truck, rail or barge
- The percentage of log volume arriving in short lengths (<4 m), middle lengths (4.1 to 8 m), and long lengths (>8 m)
- The percentage of log volume that must be fumigated onshore
- The percentage of rows that are normally open – open row percentages depend on the number of customers and the number of log types being supplied by them
- The number of book-ends available per row
- The unloading equipment available in the log storage areas – up to five types of this equipment can be selected
- The high-stacking equipment available in the log storage areas – up to four types of this equipment can be selected with one of these options being the null option
- The loading equipment available in the log storage areas – up to five types of this equipment can be selected with one of these options being the null option
- The row-to-shipside or berthside equipment available in the log storage areas – up to six types of this equipment can be selected
- The user can select whether the logs are moved from row-to-shipside direct or from row-to-shipside via berthside
- The user can select whether all areas within the port are common storage areas or if some have been allocated to individual customers.

When the search for the optimal layout is initiated the following approach is used. Each storage area is first split into blocks, travel corridors and high-stacking equipment access ways whose dimensions depend on the type of equipment used (Figure 1). Blocks are laid down in a serpentine pattern.

Each block is then allocated a long length class and its volume calculated based on the row height allowed in the block (dependent on high-stacking machine, fumigation, log length class and ground surface type). The volume in the block is then adjusted for use of book-ends, fumigation, common storage and open rows.

All of the costs for handling logs in each block are then calculated based on the equipment selected and productivity equations. Total times for row-to-ship activities are also calculated for the block. Volumes, costs and times are summed for each block to arrive at storage area volumes, costs and times.

The optimisation criteria weighting factors are then applied to area volumes, area costs and area row-to-ship times to obtain an area solution value, which is also the best value for the area for the first iteration through the search. The layout of blocks and equipment selected within areas is remembered for the best value solution.

Once the search is completed for all layouts (which include variations in block length and row direction), and equipment mixes for each area, the best values from all areas are summed to arrive at total volumes, total costs and total row-to-shipside times for the port.

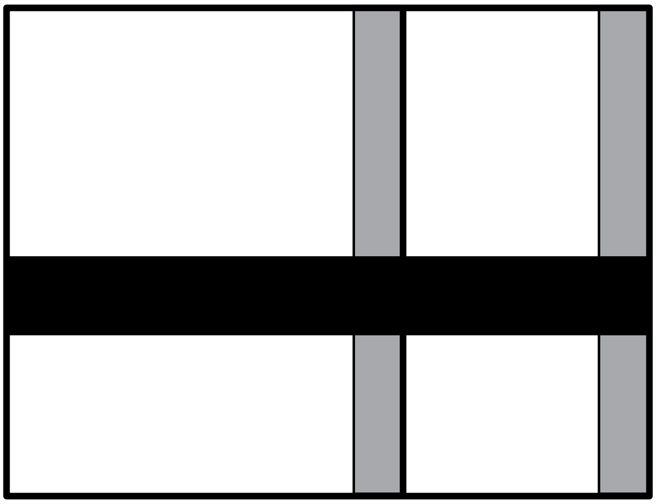

Figure 1: Example layout of travel corridors (black) and blocks (white) with attached high-stacking equipment access ways (grey) in a log storage area

## Demonstration of capabilities of OPTILOGS

The demonstration is based around a 4.75 ha fictional port, called MyPort, and focuses on maximising storage capacity. Minimising cost and row-to-shipside time will only be briefly referred to. The results of the demonstration are provided in Figure 2.

MyPort is an amalgam of pieces of three real-world ports from around New Zealand. MyPort is a simple port in that has been split into seven log storage areas. Six of the areas are on sealed surfaces and one on an unsealed surface. Most of the logs arrive by truck (90%), but a small portion of them arrive by barge (10%). Sixty percent of the logs are less than 4 m in length and 40% between 4.1 m and 8 m. Fumigation of logs (15%) is carried out at MyPort and can be done on five of the six sealed areas.

Six customers export logs through MyPort and some customers have specific storage areas allocated to them. Open rows normally account for 35% of the total number of rows. Storage capacity is increased by high-stacking where appropriate. Book-ends are currently not used at MyPort. Logs are moved direct from row-to-shipside. Log-handling equipment at MyPort includes a small pivot-steer wheeled loader for unloading barges, large pivot-steer wheeled loaders for unloading and loading trucks and for moving logs from row-to-shipside, a small material handler for high-stacking logs, and shuttle trucks for moving logs from row-to-shipside.

For this combination of storage areas and equipment (herein the base scenario), OPTILOGS calculated a total storage capacity of 14 136 JAS m$^3$ ha$^{-1}$. When 70% of the optimisation weighting was allocated to minimising costs and 30% to maximising storage capacity, OPTILOGS calculated a total storage capacity of 13 814 JAS m$^3$ ha$^{-1}$, a reduction of 2% compared with the base scenario.

When the open row percentage was set to zero, and all other variables remained as stated for the base scenario, OPTILOGS calculated a total storage capacity that was 21% higher than the base scenario. The situation where 0% of the rows were open is a theoretical maximum. This situation would only occur when exactly the right volume of every log type was delivered to the port at exactly the right time and no logs were being loaded on-ship.

Debarking of logs is being considered as an alternative to fumigation for some international markets. When the proportion of logs fumigated was set to 0%, OPTILOGS calculated a total storage capacity that was 2% higher than the base scenario.

Book-ends increase storage capacity. OPTILOGS calculated total storage capacity that was 10% higher for one book-end per row and 16% higher for two book-ends per row than the base scenario. The increase in the capacity will depend on row lengths; increases will be higher with shorter row lengths.

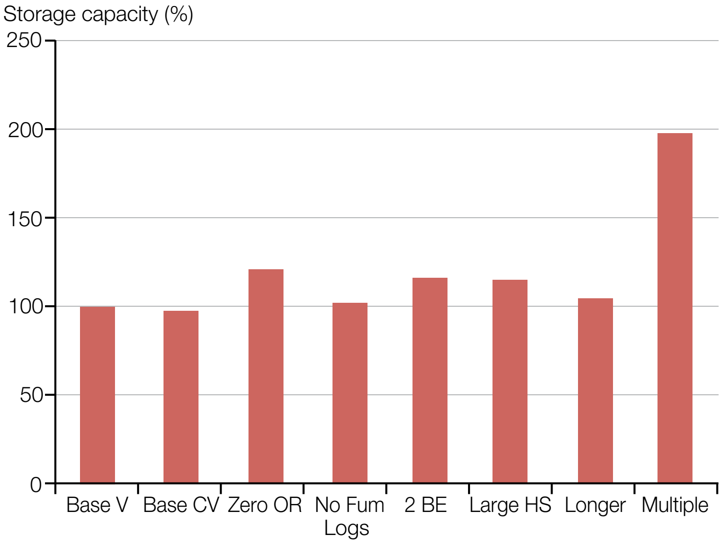

Figure 2: Relative improvements in log storage capacity at a fictitious port as determined through the use of the OPTILOGS model. BaseV = base scenario focusing on volume maximisation, BaseCV = base scenario with a mix of cost minimisation and volume maximisation foci, Zero OR = 0% open rows, No Fum = no fumigation, 2 BE = up to two book-ends per row, Large HS = large high-stacker, Longer = a log length distribution with greater proportions of logs in mid-length and long-length categories, and Multiple = multiple changes

The gains in storage capacity by using medium or large high-stackers were evaluated with OPTILOGS for MyPort. Increases in total storage capacity of 7% and 15%, respectively, were calculated by OPTILOGS. Increases were limited by fumigation requirements and unsealed surfaces in part of the log storage area.

There has been a marked increase in the percentage of short logs exported from New Zealand since the year 2000. In the 1990s, the majority of the volume was exported in long lengths (>8 m). Today, most of the volume is exported in short lengths. The impact of changing the log length distribution from 60% shorts, 40% mids and 0% longs at MyPort to 35% shorts, 50% mids and 15% longs, i.e. somewhere between current and 1990s export log length distributions, would be to increase total storage capacity by 5%.

Total storage capacity could be increased by 98% if multiple changes were made. These were assumed to be: providing up to two book-ends per row, sealing all log storage areas at the port, assigning all storage areas as common storage, using a big materials-handling machine for high-stacking, reducing the open row percentage to 20%, and receiving logs with a length distribution of 35% shorts, 50% mids and 15% longs.

To attain this level of increase in storage capacity would require changes from three groups within New Zealand ports – port authorities, log marshalling companies and log exporters. Port authorities or log suppliers are responsible for supplying book-ends, sealing log storage areas, and allocating areas to individual customers or to common storage. Log marshalling companies are responsible for supplying high-stacking, as well as other log-handling equipment. Log exporters are responsible for determining the log length distributions and affect the open row percentages.

## Concluding comments

For both value and volume, forestry is one of New Zealand's largest export sectors. A doubling of log volume exports is likely within the next decade. This will put added pressure on port-handling facilities and increase the need for productivity enhancements and optimisation of storage. Development of the OPTILOGS model and its application at three real-world case study ports, as well as a fictitious port, has helped to quantify potential gains in log storage capacity and log-handling costs. Gains depend on individual port characteristics, but the relative impact of changes described for the fictitious port are not dissimilar to those found for the three real-world ports.

As with all the models, the conclusions drawn from carrying out scenario analyses are only as good as the assumptions included in the model and the data supporting it. The assumptions have been based on discussions with staff from New Zealand's largest on-wharf logistics provider and the data supporting the model were the best available at the time the model was built. Not all log-handling equipment sizes and types were included in OPTILOGS. New pieces of equipment could be added, but these will first require new production studies to be carried out and equipment costings to be completed. Further validation of, and improvements to, the model will come from its future use.

Finally, although OPTILOGS was developed to optimise log storage and handling at port facilities it could also be applied to the layout of, and equipment selection in, sawmill yards and central processing yards.

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