SALE OF LOGS BY COMPETITIVE BIDDING USING LINEAR PROGRAMMING TO MAXIMISE THE RETURN TO THE GROWER

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ABSTRACT

A computer-assisted method for the sale of logs is described. This system uses linear programming to maximise the return to the grower while enabling the processors to specify the log qualities required. The optimal log allocation is achieved without sorting logs into more classes than can be economically justified.

The system offers benefits to both the growers and processors, but will only be viable under a specific set of conditions. The need for the system will become more apparent as the old crop radiata pine is cut out and more new crop logs become available for processing. The system also offers the potential for process productivity improvement.

INTRODUCTION

A computer-assisted method for the sale of logs is presented in this paper. The system enables the grower to offer his logs for sale in terms of identifiable sizes and grades, while processors are invited to bid for the log qualities best suited to their available equipment and product requirements. By using linear programming to maximise the return to the grower, logs can be sold by log quality classes without physically sorting them into more classes than can be economically justified.

This method for the sale of logs is in line with the principle that the market "should set the price for state exotic wood, on the basis of competitive tendering or auction, where appropriate" as recommended by the Stumpages Working Party of the Forestry Development Council (1972). The policy was reviewed by the Working Party on the Sale of State Wood of the 1981 New Zealand Forestry Conference and the principle reaffirmed.

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Because most exotic logs sold in New Zealand originate from State-owned forests, Forest Service sale agreements tend to be followed by private producers. Any new system for the sale of logs will therefore have to have the support of the Forest Service.

Current log sales involve only a few log grades, such as peeler logs, large and small sawlogs, and pulplogs. Only minimum quality standards, in terms of diameter and shape, are applicable to each log grade.

The present system of log allocation in terms of a few fixed log grades has been acceptable because of the homogeneity of size and quality of the old crop radiata pine currently being harvested. New crop radiata pine is expected to be more variable because of the large range of silvicultural regimes practised (Williams, 1982).

Because of this increased variability, it becomes more important to identify various log qualities and be able to allocate them to the most appropriate end users. Techniques such as MARVL are available to assess the recoverable volume by log types before harvesting (Deadman and Goulding, 1979) and this inventory information is necessary for any log allocation system. By defining logs, not as sawlogs, but in terms of physical characteristics such as small branched or uninodal logs at the time the trees are cruised, the need to define a sawlog is delayed until the log resource is matched with the available processing capacities and the value of the logs in the market place. Only when this information is available can a sawlog or pulplog be defined in terms of acceptable grade characteristics and diameter classes.

The method of log sale that will described can be used to assist the seller to evaluate bids for the available log resource and to calculate the acceptable grade and diameter classes to be allocated to each of the processes. Because the actual log allocation is mainly by destination there is no need to physically sort logs into more classes than can be economically justified. This can reduce the need for expensive log merchandisers (Williston, 1976).

Matching of the known timber resource, as estimated by the MARVL inventory assessment system, with the bids received from a variety of buyers can be achieved by means of a linear programming model. The model can maximise the return to the grower by allocating logs to those processors who submitted the most acceptable bidding packages. This means that logs are allocated in a rational manner and all sellers and buyers are fully aware of the procedure used to determine allocation priorities. Logs need only be sorted into those quality classes that can be economically justified.

The proposed computer-based system appears to offer a means to increase sawmilling productivity and this aspect is discussed later.

MATHEMATICAL FORMULATION OF THE PROBLEM

Because of the complexity of handling and evaluating a large number of bids for logs by log quality and diameter classes, a computer-based system is necessary. A computer program for the sale of logs by competitive bidding using the Simplex method of linear programming (Dorn and Greenberg, 1968, p. 114) to maximise revenue to the wood grower was developed. The programe is called SALE and is written in FORTRAN IV and requires a virtual memory computer to handle large scale problems. A listing of program SALE is available from the author.

The objective is to maximise the revenue to the grower by allocation of the available logs subject to the constraints imposed by the various bidders. This can be done as follows:

Maximise revenue z

$$\text{where } z = \sum_{k=1}^{p} \sum_{j=1}^{m} \sum_{i=1}^{n} P_{ijk} \cdot X_{ijk}$$

P_{ijk} = price in dollars per cubic metre bid by company k for log quality j and diameter class i

X_{jik} = volume in cubic metres of logs of quality j and diameter class i to be allocated to bidder k

n = number of log diameter classes

m = number of log quality classes within each log diameter class

p = number of companies bidding for logs

The revenue is maximised subject to the following constraints.

(i) *Log supply constraints*

$$\sum^{p} X_{ijk} \leqslant Q_{ij}$$

for $i = 1 \ldots\ldots\ldots\ldots n$

$j = 1 \ldots\ldots\ldots\ldots m$

where Q_{ij} = volume of log quality ij available within log diameter class i.

(ii) *Log demand constraints specified by the bidders*

Each bidder can specify an upper limit on the volume of logs of each diameter and quality class allocated to him.

$$X_{ijk} \leqslant D_{ijk}$$

for $i = 1 \ldots\ldots\ldots\ldots n$

$j = 1 \ldots\ldots\ldots\ldots m$

$k = 1 \ldots\ldots\ldots\ldots p$

where D_{ijk} = volume limit specified by bidder k

(iii) *Total log demand constraints specified by bidders*

Each bidder can also specify a limit on the total volume of logs to be allocated.

$$\sum_{j=1}^{m} \sum_{i=1}^{n} X_{ijk} \leqslant E_k$$

where E_k = maximum volume limit specified by bidder k.

(iv) *Total value of logs allocated to each bidder*

Each bidder can also specify a limit on the total value of all logs to be allocated.

$$\sum_{j=1}^{m} \sum_{i=1}^{n} P_{ijk} . X_{ijk} \leqslant F_k$$

for $k = 1 \ldots\ldots\ldots\ldots p$

where F_k = Maximum value limit specified by bidder k.

This constraint can also be used by the wood grower to limit sales where bidders are subject to credit limits.

EXAMPLE OF THE SALE OF LOGS BY COMPUTER

To illustrate the principle of this method for the sale of logs, a simple hypothetical log sale is presented. Table 1 contains the data on the log supply available for sale.

For the example three bids were received. Two bids were from solidwood processors who regard log quality as very important and one bid was from a fibre processor who does not attach a premium to log quality or size.

TABLE 1: LOG SUPPLY AVAILABLE FOR SALE

Log Diameter Class (mm) From	To	*Log Quality*	*Log Volume Available (m^3)*
100	200	A	10
100	200	B	15
100	200	C	5
201	300	A	20
201	300	B	5
201	300	C	2
301	400	A	25
301	400	B	10
301	400	C	1

Every bidder had to specify the following:

(1) The price he is willing to pay for each log quality within each of the log diameter classes.
(2) The maximum volume of each log quality within each log diameter class he is willing to accept.
(3) The maximum total volume of logs he is willing to accept.
(4) The maximum value of all logs to be supplied.

The following bids were received:

Processor 1, a sawmiller, presented the bids listed in Table 2.

Processor 2, a plywood manufacturer, bid $20/m^3$ for 18 m^3 of A quality logs from diameter classes 201 to 300 mm and 301 to 400 mm with a maximum limit of 20 m^3 from both diameter classes.

Processor 3, a pulpmill, bid $5/m^3$ for a maximum of 100 m^3 of logs from any quality or diameter class.

TABLE 2: BIDS RECEIVED FROM PROCESSOR 1, A SAWMILL

Log Description *Log Diameter Class* From	To	*Log Quality*	*Price Bid* ($/$m^3$)	*Maximum Volume* (m^3)
100	200	A	10	10
100	200	B	5	10
100	200	C		
201	300	A	15	20
201	300	B	10	20
201	300	C		
301	400	A	20	20
301	400	B	15	20
301	400	C		

Maximum volume to be supplied: 50 cubic metres
Maximum value to be supplied: $700

The optimal solution to the problem was calculated using program SALE. The solution indicates that the maximum revenue to wood grower would be $1212.50 with logs allocated to the bidders as shown in Table 3.

TABLE 3: ALLOCATION OF LOGS TO SUCCESSFUL BIDDERS

Log Diameter Class (mm) From	To	*Log Quality*		*Log Volume Allocated* (m^3)
Log allocation to bidder No. 1:				
100	200	A		2.5
201	300	A		5.0
201	300	B		5.0
301	400	A		20.0
301	400	B		10.0
			Total	42.5
Log allocation to bidder No. 2:				
201	300	A		15.0
301	400	A		5.0
			Total	20.0
Log allocation to bidder No. 3:				
100	200	A		7.5
100	200	B		15.0
100	200	C		5.0
201	300	C		2.0
301	400	C		1.0
			Total	30.5

In this example three successful bidders were identified. In practice many more bids may be received and some bidders allocated only very small volumes which might not be economical to sort. By re-running the program and by introducing additional constraints, a cut-off point can be determined where the cost of log making and log sorting exceeds the additional revenue that can be obtained by accepting an additional bid.

A log making specification is prepared only after the bids have been evaluated and accepted.

This simplified example illustrates the concept of competitive bidding. In real life the problem will be much more complex with about 9 log quality classes, 5 to 15 log diameter classes, and 3 to 20 or more companies bidding for logs. More constraints might also have to be added to allow for social objectives such as maximising employment or net foreign exchange earnings.

The example used does not fully illustrate the power of a computer-based system of log sale. Commercial mathematical programming software is available that can be programmed to allocate log supplies from a large number of forests, schedule harvesting and transport operations, and ensure a rational allocation of logs and wood residue. It is also possible to incorporate the exchange of logs in one area for logs or wood residues in another area.

DISCUSSION

As shown by the simplified example in the previous section, the computer-based method of log sales overcomes the problem of matching the demand for logs of an acceptable quality with the supply potential from the forest. It enables the grower to offer his forest for sale in terms of a large number of identifiable log diameters and grades. It also enables the processors to bid for those log diameters and grades best suited to their process requirements.

The system offers the following advantages:

(1) The ability to maximise the value of a given supply of logs; while

(2) Limiting the number of log sorting classes to those that can be economically justified; and

(3) Satisfy the processing requirement of processors within the limits imposed by the available log supplies.

The system is, however, only applicable under a very specific set of conditions.

The first requirement is for logs to be of variable quality. A wide range of log grades and diameters makes it difficult to allocate logs correctly without some formal system to match supply and demand. Both between log and within log variability must be catered for. The mathematical formulation described in this paper is applicable to between log variation only but can be easily expanded to allow for within log variation.

The solid line in Fig. 1 illustrates the general relationship between sawmill profitability and log small end diameter. This general relationship is applicable to most sawmills (Flann, 1981) but different log qualities and sawmill designs can cause the profit line to shift to favour smaller or larger logs. Some sawmill designs can also cause profit to peak before reaching the maximum log size than can be processed.

The dotted lines in Fig. 1 show that sawmill profitability for individual logs is widely scattered around the mean. This large range is mainly due to log quality variability and indicates that some log qualities make a large contribution to sawmill profitability. It also indicates that some logs are of such low quality that they should not have been allocated to the sawmill at all. Figure 1 is based on a sawing study using old crop radiata pine as supplied to a sawmill. The new crop radiata pine is expected to exhibit an even greater degree of between log variation than the old crop (Bunn, 1981).

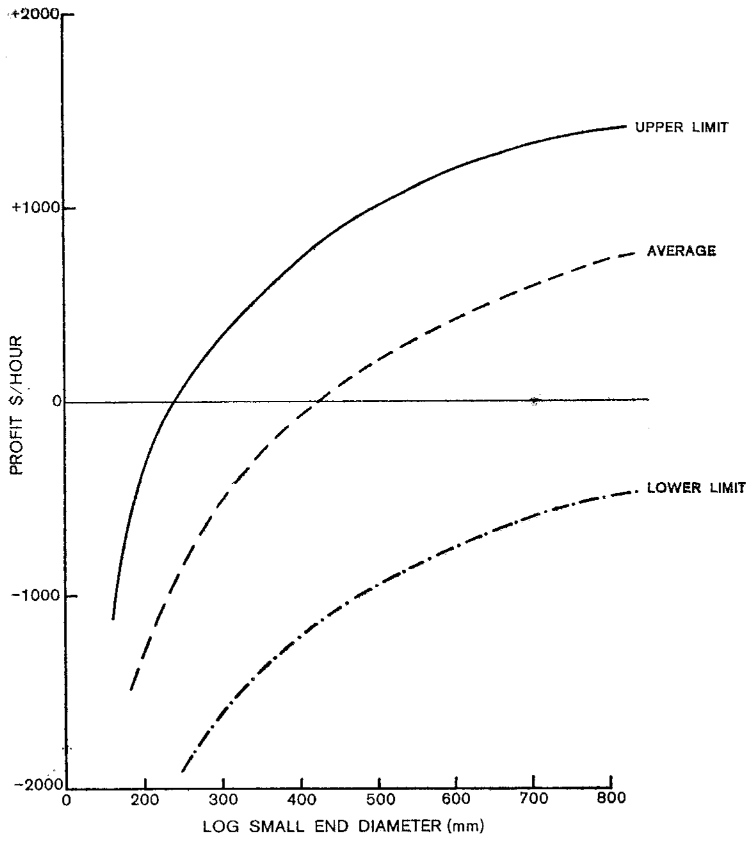

FIG. 1: *Idealised relationship between sawmill profitability and log small end diameter.*

Source: Sawing study done by author in a modern New Zealand bandmill in the central North Island using old crop radiata pine as supplied to the sawmill. (Actual data available on request with the consent of the sawmill).

The wide range of log values, measured in terms of their contribution to sawmill profit, suggests that log small end diameter alone is a poor measure for log allocation for the new crop radiata pine. A system using log diameter and log grade is therefore required to deal with the wide range of between log qualities expected from the new crop radiata pine.

The second requirement is for the log variability to be identifiable in terms of log diameter and grade classes. A pre-harvest inventory assessment system called MARVL (Deadman and Goulding, 1979) is available and can be used to identify the relevant log qualities for allocation purposes. This means the compartment of timber to be offered for sale must be sampled and the available log qualities identified (or predicted in the case of internal defects) and recorded. The pre-harvest inventory assessment system used these data to predict the volume of various log qualities that can be recovered from the compartment sampled. Program MARVL is being used by the larger forestry companies in New Zealand and this aspect should not present any problems provided grade classes relevant to the various processors' requirements can be correctly identified.

A standardised classification of log is required to enable all buyers to make their purchasing decisions on the basis of log characteristics only. This is especially important where a number of log suppliers are pooling their resources. Agreement on log quality specifications is very difficult and it may be impossible in practice to get a large number of log buyers to come to some form of agreement. A computer-based system can handle more variables than a manual system and should, theoretically at least, be capable of satisfying the requirements of most processors.

The following log quality classes are suggested and can form the basis for discussion when standards are to be agreed.

AP Best quality pruned logs
BP Second best quality pruned logs
CP Third quality pruned logs
LI Part pruned or long internode logs
A Best quality unpruned logs
B Second quality unpruned logs
C Third quality unpruned logs
S Short logs

The third requirement is for a number of processors with different log quality requirements to be competing for a limited supply of logs. A wide range of processing options, with different requirements in terms of log diameter and grade classes, are available. Figure 2 illustrates two sawmilling systems, each with its own contribution towards profit versus log diameter characteristics. These two sawmilling systems represent a typical band heading with a log carriage as used for processing old crop

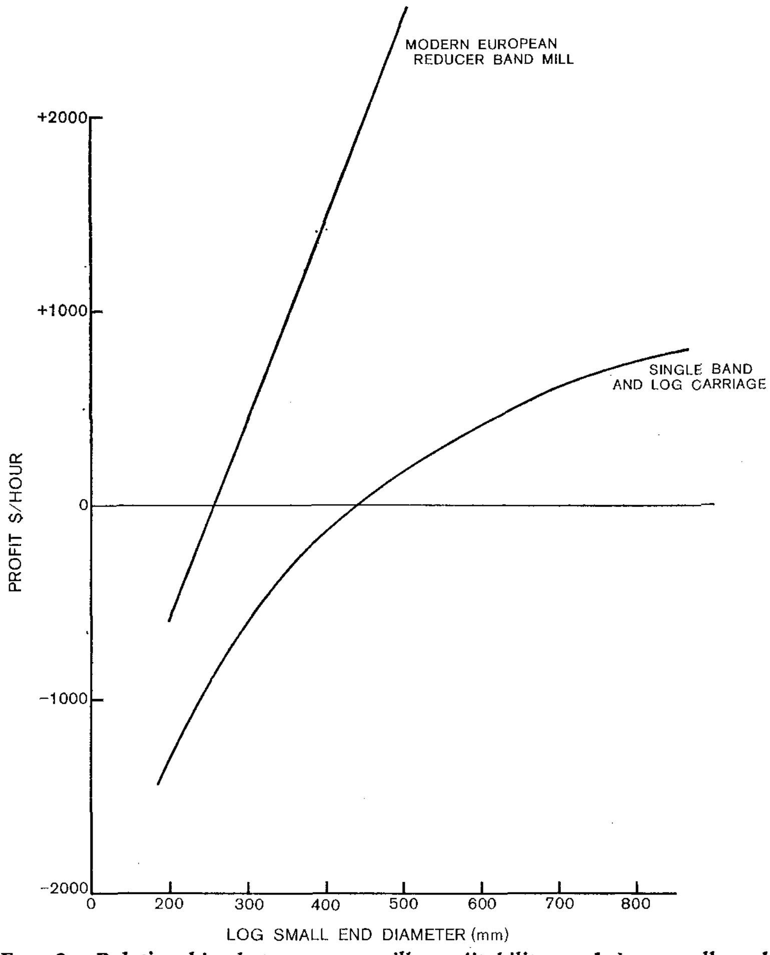

FIG. 2: *Relationship between sawmill profitability and log small end diameter for different sawing systems.*

Source: Calculated by author using equipment specifications as supplied by the manufacturers and using the procedure to set production standards as described by van Wyk (1982). *Note*: The profit lines are very dependent on log grade, as indicated in Fig. 1.

radiata pine and a reducer band mill designed for the processing of new crop radiata pine. Many different sawmill designs are available each with its own performance characteristics. The two sawmilling systems illustrated in Fig. 2 should not be regarded as representing the extreme limits of sawmill performance because other designs are available favouring smaller or larger logs than those illustrated. A third dimension, log grade, is not shown in Fig. 2 but must also be taken into account when allocating logs.

The system offers benefits to both the growers and processors. The major benefits to the grower are the ability to maximise revenue from a given crop of trees and limit the number of sorting classes to those that can be economically justified. The system can also be used by growers to review their harvesting schedules to achieve their objectives within the constraints imposed by market conditions.

The benefits to the processors include the ability to bid for small or large quantities of those log quality classes best suited to their process requirements. It also offers processors the opportunity to eliminate or restrict the number of uneconomical logs processed.

The system outlined in this paper describes a possible solution to a problem which is not yet with us but will become more apparent as the old crop radiata pine is cut out and more new crop logs become available for processing. The real benefits of the system will only be realised when a wide range of log qualities are available in sufficient quantities to attract a number of processors with different log quality requirements.

It is most likely that the system of log sale described will be implemented in the form of a log exchange (Malloy, 1981: Forestry Council, 1981) with the log supply potential of both large and small growers being pooled. This should ensure the most rational allocation and use of logs.

PRODUCTIVITY IMPROVEMENT POTENTIAL

At first glance the advantages of correct log allocation may appear to be self-evident. There is also, a strong body of research on process evolution (Abernathy and Townsend, 1975) which supports the need for a more rational log allocation system. These workers believe that processes develop in a consistent and identifiable manner — from unco-ordinated, through segmental, to systemic stages.

For processes to develop, and hence for productivity to improve, a minimum degree of evenness in advance among productivity factors such as raw material, technology, labour, scale, and product are required.

By applying the model developed by Abernathy and Townsend to the sawmilling industry in New Zealand, it appears that log supply is in the unco-ordinated stage of process development while the technology, labour, scale, and product factors are in the segmental stage. It therefore appears that raw material supply is preventing an even advance in productivity improvement in existing sawmills.

Any further advances in sawmilling productivity to the systems stage of development will require very strict log specifications and for the log supply process to be integrated into the overall process design.

This analysis into process evolution supports the need for a more rational method of log allocation where the tailored log specifications are imposed on the supplier.

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