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PROJECT REPORT

TRUCK DESPATCHING CASE STUDY

The Cost Efficiency of Log Truck Despatching in Hawke's Bay

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Project Report

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ABSTRACT

LIRO used a computer model to perform a retrospective analysis of log truck scheduling efficiency in Hawkes Bay, with the co-operation of Pan Pacific Forest Industries. Computer generated schedules were compared with records of manual despatching decisions for 16 days of transport operation.

The assessment of scheduling efficiency presented in this report is based on a mathematical model. A model may give helpful insight and useful results, but it is not reality. This must always be borne in mind. An estimate of scheduling efficiency should in no way be construed to be a performance assessment of any individual, be it the transport manager, the despatcher, or anyone else. Scheduling efficiency is a product of the whole system.

In this report, scheduling efficiency has been estimated in hindsight. Much of the information necessary for devising a really efficient schedule is available only after the event. Decisions made in an imperfect world, with imperfect information, seldom come out perfectly. This applies as much to computer-aided despatching as it does to manual despatching.

Pan Pac's scheduling efficiency was calculated at 95.8%. Two areas were identified for potential improvement: reducing the number of trucks used ($900/day), and improved back loading ($350/day). How much of this potential saving can actually be achieved remains an open question.

ACKNOWLEDGMENTS

LIRO acknowledges the assistance of Pan Pacific Forest Industries for their co-operation in this project.

INTRODUCTION

Log Transport

The New Zealand forest industry spends over half a million dollars a day on transporting logs by truck. Transporting logs from the forest to the customer costs as much as all the other harvesting operations (felling, extraction, delimbing, log making, sorting and stacking) combined. Even a modest reduction in this cost would save the industry millions of dollars a year and improve its competitiveness in the world market.

The industry has tended to look to truck technology for cost savings, and it seems that each generation of log trucks is lighter, stronger and more versatile and efficient than the last. This process of continual improvement shows no signs of stopping, or even slowing; recent innovations include central tyre inflation, on-board computers and Global Positioning Systems (GPS).

On the other hand, very little has been done in the area of log truck scheduling and despatching.

Scheduling and Despatching

In New Zealand, managing log transport is generally the responsibility of the supplier, namely, the forest owner. Transport management is performed at a number of levels, from the strategic planning of roads, to the tactical co-ordination of trucks and loads, that is log truck scheduling and despatching.

Central co-ordination of the truck fleet is necessary because:

- The truck drivers need to know where the loads are
- Only one truck can be assigned to any load
- Skilful co-ordination can greatly reduce the overall cost of transportation.

It might appear that assigning trucks to loads is trivial, but nothing could be further from the truth. Good co-ordination can:

- Reduce unloaded travel between delivering a load and picking up the next one
- Ensure that customers receive the right logs at the right time
- Reduce delays at forests and customers by smoothing out the flow of trucks
- Prevent accumulation of logs in the forest
- Make sure each driver gets a full day's work.

As this list shows, the *direct financial* benefits of good truck co-ordination are enjoyed mostly by the *truck operator*, not by the forest company. It is assumed that some of these benefits will flow back to the company eventually. In addition, although the other benefits are more difficult to quantify, they can be just as important to the forestry company.

Truck co-ordination can be achieved by scheduling or despatching, or a mixture of the two. *Scheduling* implies a prepared plan of truck movements for the whole day in advance, while *despatching* implies that decisions are made as the need arises.

Scheduling has some advantages. The scheduler is not plagued by constant interruptions, and can think of the day as a whole. Unfortunately, unexpected delays and breakdowns during the day can soon make nonsense of the prepared schedule.

Despatching is often better than scheduling because more is known at the time of despatch than could have been known at the beginning of the day. Not only can a despatcher adapt to delays, but he or she can also take advantage of any drivers running *ahead* of schedule. Nevertheless, a *human* despatcher does not have time to consider all the possible options.

In practice, the distinction is not always so sharp; a despatcher can do *some* forward planning, and a prepared schedule may be very useful, particularly at the start of the day.

Computer-Aided Despatching

Computer-aided despatching offers the best of both worlds; the foresight of a prepared schedule, and the flexibility of a despatcher. In New Zealand, many industries (taxis, ambulances, emergency vehicles and police) have used computer-aided despatching for a number of years, and some work has also been done in forestry overseas.

It is important to realise that despatching emergency vehicles is not the same thing as despatching log trucks. Emergency vehicles need *rapid response* to an *unpredictable demand*, and the most urgent cases are the least predictable. Log trucks deal with supply and demand that changes only slowly, and there is a much greater incentive to plan ahead. There is a difference between saving lives and saving money!

A computer-aided despatching system would probably not stand alone; it should be integrated with inventory management, accounting and reporting functions. The costs and benefits of such integration are not easy to quantify.

Communications between the despatch system, the trucks, the loader drivers and the customers can be automated using electronic data interchange. For instance, there is a Wellington taxi company that has data entry personnel but no despatchers nor radio operators.

Even if computer-aided despatching did not replace human despatchers altogether, it could reduce stress, training time, and staff turnover and numbers.

At present, LIRO has no plans to produce a useable despatching aid. However, where requested LIRO will *advise* its members on this subject.

The question naturally arises: What benefits will computer-aided despatching bring to the New Zealand forest industry?

This, in turn, hinges on the question:

How efficient is the current manual log truck despatching in New Zealand?

THE STUDY

LIRO has performed a study to determine the cost efficiency of "manual"[1] log truck despatching at Pan Pacific Forest Industries (Pan Pac) in Hawkes Bay. This study has been performed with the full co-operation of Pan Pacific Forest Industries, and in particular Neil Weber (Log Transport Supervisor).

This is the first in a series of case studies (Robinson, 1994a) to determine:

- The efficiency of manual despatching in the New Zealand forest industry
- The potential savings that might be obtained by computer-aided despatching.

[1] They *do* have a computer but it doesn't make scheduling decisions.

The Pan Pac study is based on sixteen days of transport operation in August, 1993. These "manual schedules" are compared against optimal schedules created using a variety of computer techniques (Robinson, 1993, 1994b and 1995). Schedules are compared on the basis of cost calculated using standard truck costing procedures (Goldsack, 1988). The efficiency of any schedule is then:

$$\textit{efficiency} = \frac{\textit{cost of optimal schedule}}{\textit{cost of actual schedule}} * 100\%$$

Scheduling efficiency is based on direct trucking costs, rather than on company haulage rates.

By contrast, transport managers have tended to measure their success in terms of loaded running percentage:

$$\textit{loaded running percentage} = \frac{\textit{loaded distance}}{\textit{total distance}} * 100\%$$

This is much easier to calculate, and has some relevance to back loading, but on the whole is worthless as a measure of schedule quality. This is because it takes no account of *slack time*, the main form of inefficiency.

In this study, no attempt was made to assess customer satisfaction, nor to determine the customer benefits from automated scheduling.

The Truck Fleet

The trucks used by Pan Pac may be divided into three classes:

- Eleven trucks owned by Pan Pac and driven by salaried employees
- Thirteen owner operators on permanent contract with Pan Pac
- Seven casual contractors.

Together, the direct employees and permanent contractors constitute the Pan Pac base fleet. Pan Pac has a long term relationship with these operators and does its best to keep them in full employment. As far as possible, these 24 trucks share the work equally. In effect, Pan Pac is committed to paying the standing costs of these vehicles regardless of the wood flow situation. This means that there is no incentive to produce a schedule with fewer than 24 trucks. Cost savings must come from:

- Reducing the running costs of the basic fleet by back loading
- Reducing the use of casual contractors.

PAN PAC'S DESPATCHING

Given the uncertainties of supply, demand, weather and truck performance, it is very difficult to plan truck movements more than a few hours in advance. Nevertheless, Pan Pac plans as far ahead as possible, and more than half of the truck operators know their whole day's trips in advance. The other units know at least their first load, (sometimes two or three), and call up the despatcher on the radio to get their next assignments.

The moderate size of the truck fleet means that one despatcher is sufficient. The pressure on the despatcher does not seem to be as heavy as at some of the larger forestry companies. Pan Pac has a dedicated despatcher, and the log transport supervisor also lends a hand.

Compared with many companies in the forest industry, Pan Pac has a fairly high-tech transport information system. Pan Pac has a fully automated weighbridge, and all its deliveries are recorded in a computer database. The database also holds details on forest compartments which are used for despatching and costing.

Rating Forest Compartments

Pan Pac has quite a considerable database to assist with transport planning and truck despatching. One of the database tables lists every forest compartment, along with its species, distance from the Pan Pac mill, the loader operating in the compartment, and other details. Most importantly, each compartment is assigned a number called "loads per day". This has nothing to do with harvesting productivity, rather it indicates the number of trips that a truck could make between that compartment and Pan Pac in a day.

For example, if a compartment is rated at three loads per day, this means that a truck hauling out of that compartment could make three trips a day, or one trip in a third of a day. Compartments may also be rated with part trips: 2.75 trips per day, for instance.

This is an empirical system based on years of practical experience. Log Transport Supervisor, Neil Weber, relied heavily on this rating scheme when assessing the feasibility of computer generated schedules.

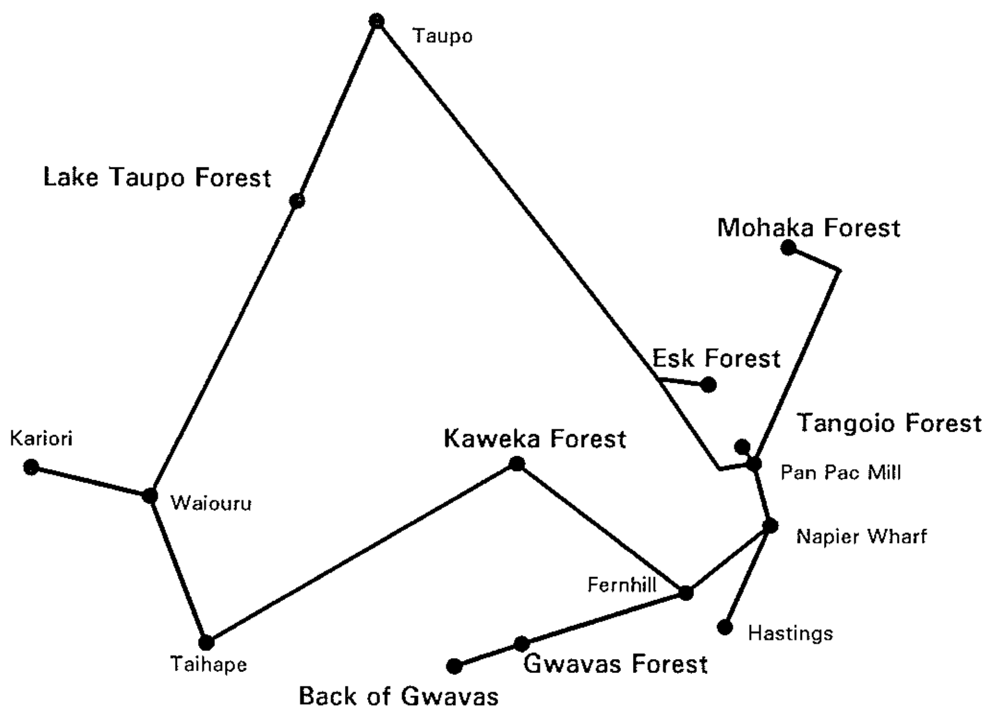

Figure 1: A simplified map showing major Hawkes Bay forests and roads

The rating system is used for:

- Truck scheduling
- Wood flow planning
- Payment to truck contractors
- Work equalisation for "permanent" contractors and Pan Pac's own drivers.

The last point is interesting: Pan Pac keeps a record of how much work each driver has done, and gives priority to drivers who have been missing out.

Rating each forest by "loads per day" is a useful strategy for Pan Pac, because the majority of log loads are brought to the Pan Pac mill at Whirinaki, and most of the rest are delivered to the Port of Napier, which is only 20 minutes away (Figure 2). Back loads and more distant mills are rated in a similar way, but using a different database table.

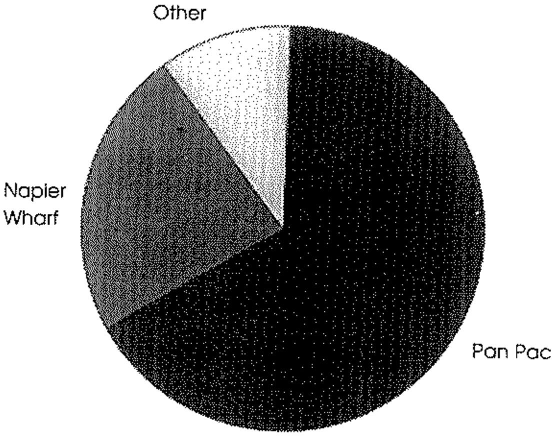

Figure 2: Destination of logs delivered by Pan Pac during August, 1993

While this rating system is extremely useful for practical scheduling and despatching, it is not precise enough for costing and time simulation. It was, therefore, decided to enter the roading system into the computer and calculate times and costs directly. It was not until this had been completed that the full simplicity and effectiveness of Pan Pac's rating scheme became apparent!

At first sight, the obvious way to enter the road network into the computer is through a Geographic Information System (GIS). Early experiments with GIS at LIRO produced disappointing results. Use of a digitiser tablet made it easy to enter road networks in all their natural complexity - quite unnecessary in this application. On top of this, there seemed to be no way to get the information out of the GIS in a useful form. In the end, the road network was compiled by measuring maps and typing the results into a spreadsheet. The final network had 106 nodes and 111 links, greatly simplified in Figure 1.

The Pan Pac mill is just north of Napier, next to the Whirinaki power station, and the main forests in the area are Esk and Mohaka to the North, Kaweka to the West, and Gwavas to the South. Mohaka is reached via State Highway 2, Gwavas by State Highway 50, and Kaweka by the Napier-Taihape Road. Use is also made of the Napier-Taupo Road (State Highway 5), and various other parts of the state highway network. Forest roads make up a very small proportion of the total distance, so these can be given fairly superficial treatment.

Back Loading

Mills outside the immediate Napier area are more important than Figure 2 suggests because they are the key to Pan Pac's *back-loading* strategy.

Without the outside mills, Pan Pac's transport operation reduces to a classical hub-and-spoke system. Trucks shuttle between Pan Pac/Port of Napier and the various forests, and on the outward trips, each truck is always empty. The loaded running percentage will always be 50%.

The outside mills provide an opportunity to carry logs *away* from Napier as well as *towards* it; this improves the loaded running percentage, increases profitability and makes better use of the trucks. In particular, loads from Lake Taupo Forest are offset by deliveries to Taupo, Rainbow Mountain (south of Rotorua) and Kariori.

Scheduling Objectives

For the purposes of this study, the aim of a truck schedule is to ensure that:

- All the days loads are picked up and delivered within the specified time windows (this is assumed to be the sole measure of customer satisfaction)
- The transport cost is as small as possible
- The schedule complies with New Zealand law and company policy.

In practice, the third point boils down to a limit on driver hours. Queueing was completely ignored in this study, since Pan Pac does not regard it as a problem.

The three most important elements of a schedule are therefore *loads*, *costs*, and *timing*. The timing issue may be subdivided into *standing time*, *running time* and *slack time*.

This project was a large and complex one, with many interacting parts, not all of which could be validated experimentally. In many areas, Neil Weber's years of practical experience at Pan Pac have been indispensable.

LOADS

Log Sizes and Truck Configurations

Four kinds of truck/trailer configurations are used at Pan Pac: *longs units*, *shorts units*, *convertibles* ("interchangeables") and *short shorts units*; the latter is a shorts rig with two pairs of bolsters on the trailer, allowing even shorter log lengths ("stubbies") to be carried in three packets. Within each configuration, all trucks are treated as identical.

Not all log sizes can be carried by every truck configuration: a longs unit cannot carry short logs, nor can a shorts unit carry long logs. The full compatibility matrix is shown in Table 1.

Table 1- Log truck configurations and log length

Configuration Name	Can Carry Long Logs?	Can Carry Short Logs?	Can Carry Stubby Logs?
Longs Unit	Yes	No	No
Shorts Unit	No	Yes	No
Convertible	Yes	Yes	No
Short Shorts	No	Yes	Yes

The compatibility of trucks and loads is a vital issue in designing a schedule. Unfortunately, the schedule information provided by Pan Pac specified the truck, the pickup and delivery points for each load, but not the log size. While it is safe to assume that a load carried by a longs unit consisted of long logs, it is not possible to determine the log size of loads carried by convertible or "short shorts" rigs. Thus there is no way to know what other trucks could have carried the load instead.

Therefore, it has been necessary to *guess* the log sizes in these cases. This was considered acceptable on the grounds that any errors introduced here would have little impact on calculated schedule efficiency. Nevertheless, it must be admitted that direct log size information would have been preferable.

No log grade information was available. Each log load is therefore identified by its origin and its destination. There is little scope to save money by reassigning logs to different customers in any case, so the absence of log grade information is no great handicap.

One potential difficulty is *split loads*; a truck carrying half a load of one grade on the truck, and half a load of a different grade on the trailer. When creating a schedule from scratch, this poses an extra problem which must be addressed. Split loads were not an issue in this study, because there was no grade information at all. Even if there had been, a split load could have been treated as a *full* load of a "split" log grade.

COSTS

Loading and Unloading Costs

It is assumed that loading and unloading costs are independent of the truck schedule, and that queues are not an issue. However great the log handling costs may be, if they are beyond the influence of the truck despatcher, they fall outside the question of schedule efficiency. The only way that loaders enter into the *transport cost* equation is the fact that Bell loaders are incapable of lifting down trailers from trucks. This means that a truck travelling empty to a Bell loader must travel with the trailer down, thus incurring extra Road User Charges (RUC).

Truck Costs

Trucking costs (Goldsack, 1988) can be divided into standing costs and running costs. Definitions vary, but for the purposes of this study, *standing costs* include capital costs (interest and depreciation), overheads, insurance, registration, operator profit and driver wages. This is appropriate because these are the costs that Pan Pac would have to pay for one of its own trucks even if it did no work for the day. *Running costs* are RUCs, fuel, oil, tyres, repairs and maintenance.

Standing costs are generally expressed in dollars per day. They are called standing costs because they are incurred whether the vehicle is moving or not. When the vehicle is moving it incurs running costs *and* standing costs.

All the trucks considered here are capable of carrying their own trailers when not loaded: this produces a considerable saving in RUCs. (Compare columns "Trailer Down RUC" and "Trailer Up RUC" in Table 2.) The columns "Loaded Running" and "Unloaded Running" are the running costs of the configuration excluding RUCs. It is assumed that running costs (excluding RUC) are 50% greater when the truck is running loaded.

Road user charges must be considered separately from other running costs because:

- The truck may travel unloaded with the trailer down
- Road user charges do not apply to private forest roads.

Table 2- Log truck configurations and costs (LIRO estimates)

Configuration Name	**Payload** *(tonnes)*	**Standing Cost** *($/day)*	**Trailer Down RUC** *(c/km)*	**Trailer Up RUC** *(c/km)*	**Loaded Running** *(c/km)*	**Unloaded Running** *(c/km)*
Longs Unit	28	527	70	38	67	45
Shorts Unit	29	559	55	38	69	46
Convertible	28	573	55	38	69	46
Short Shorts	29	588	55	38	69	46

For scheduling purposes, logs are measured in "loads", rather than tonnes. This greatly simplifies the calculations, but differences in payloads between the various configurations cannot be ignored. The solution adopted in this study is to divide the running cost by the payload, to get an answer in cents per tonne-kilometre, and then to multiply by a 29 tonne standard load to get a *scheduling running cost* expressed in cents per kilometre per standard load, as shown in the equation:

$$\textit{running cost for scheduling} = \textit{true running cost} * \frac{\textit{29 tonnes}}{\textit{true payload}}$$

STANDING TIME

Standing time occurs when the truck is stationary for loading, weighing or unloading operations. These affect truck scheduling in the following ways:

- Log handling operations can take place only when the machines are manned
- The schedule must allow time for loading, weighing and unloading
- The schedule must allow time for lifting the trailer on and off the truck
- Log handling machines can only deal with one truck at a time.

Hours of Operation of Loaders, Weighbridges and Stackers

Loading, weighing and unloading operations require the use of special facilities (machines and their operators). Apart from the Pan Pac automated weighbridge, these facilities work to their own timetables and are only available for part of the day. Pickups and deliveries must be scheduled to take place only during the "business hours" of the loaders, weighbridges and stackers.

In the scheduling literature, these constraints are known as *time windows*. Time windows do not seem to be a major concern at Pan Pac, except for the relatively early closing time at the Napier wharf (4:15 pm).

The starting and finishing times for loader operators are highly variable; in this study it has been assumed that all loader operators start work at 4:30 am and knock off at 5:00 pm. This is an oversimplification, but it had no impact on scheduling efficiency. The business hours of weighbridges and customers in the area were provided by Pan Pac. The log transport supervisor also expressed a preference that certain customers receive their deliveries before noon; this has been treated as an inviolable rule.

Loading Times

At the beginning of the study, no firm data was available for loading and unloading times. During the summer of 1993/94, LIRO hired a student to perform a time study and thus obtain the necessary information (Bates and Robinson, 1994). Pan Pac's own estimates agreed closely with these results.

The time a truck spends with the loader is made up of four components:

- Lift down the trailer (2 minutes)
- Prepare to load (1 minute)
- Lift logs on to truck and trailer (Table 3)
- Chain up, collect docket (3 minutes)

Using the table, the estimated *total* loading time for short logs loaded with a front end loader is thirty minutes (2 + 1 + 24 + 3).

Weighing Times

All weighing operations are considered to take exactly five minutes. Since weighing is so quick in comparison with the other operations, there is no point in studying it any further. Note, however, that if *queues* at weighbridges turn out to be a problem, weighing time becomes *vitally* important.

Table 3 - Times for lifting logs on to truck and trailer

Lift Logs With:	**Long Logs** *(minutes)*	**Short Logs** *(minutes)*	**Stubby Logs** *(minutes)*
Bell Loader	15	30	45
Front End Loader	12	24	36

Table 4 - Times for lifting logs down from truck and trailer

Lift Logs Down With:	**Long Logs** *(minutes)*	**Short Logs** *(minutes)*	**Stubby Logs** *(minutes)*
Front End Loader	12	24	36
Stacker	3	6	9
Scale and Stack	30	40	50

Unloading Times

The unloading operation has four components:

- Unchain the load (2 minutes)
- Lift logs down from truck and trailer (Table 4)
- Tidy up (1 minute)
- Lift the trailer on to the truck (6 minutes)

Logs delivered to a port for export are scaled (that is, measured) before being unloaded, hence "scale and stack" in Table 4. Scaling time is variable, and depends on log diameter as well as length. Since the transport records did not include diameter information, it has been necessary to use a "typical" time.

A truck delivering a load of short logs to a mill would be weighed and unloaded and would have the trailer raised in a total of 20 minutes (5 + 2 + 6 + 1 + 6). This makes no allowances for queueing.

Queueing

A loader, weighbridge or stacker can only deal with one truck at a time. If two trucks arrive simultaneously, one of them must wait. In the Central North Island, queueing is a big issue, perhaps the dominant one in log truck scheduling [6]. The log transport supervisor assures me that queueing is not a big problem in Hawkes Bay.

The question of queueing was examined closely in the early stages of this study, and a computer simulation was built specifically to address this issue. However, it seems that the log transport supervisor has allowed for a small amount of queueing by reducing his truck speed estimates, and the explicit simulation was discarded. No doubt it will prove useful in later studies. Although queueing is not explicitly considered in this report, at least the Pan Pac schedules and the computer schedules are compared on an equal footing.

RUNNING TIME

By far the largest part of a truck shift is composed of *running time*, the time taken in driving the truck from one location to another, with or without a load. The running time depends on two factors: the road network, already discussed, and truck speed, discussed below.

Truck Speed

The running time for a truck on a section of road may be calculated by dividing the road length by the truck speed. Truck speed is determined by a number of factors, but the most important are the load status of the truck (*loaded* or *unloaded*) and the nature of the road. Sections of road have been classified as *easy*, *medium* or *difficult*, based on their surface quality and steepness as read from the map (Groves, Pearn and Cunningham, 1987).

Speeds were initially calibrated using records from on-board computers on Pan Pac trucks (Weber, 1994). However, when the transport supervisor was shown schedules based on these truck speeds, he was not satisfied with the results, saying that the trucks were running too fast. The truck speeds were, therefore, reduced by 5% to get those shown in Table 5.

Table 5: Loaded and unloaded truck speeds, by road grade

Truck Status	Road Grade	Average Speed (km/h)
Unloaded	Easy	71
	Medium	62
	Difficult	57
Loaded	Easy	67
	Medium	52
	Difficult	36

On residential roads, the average speed was reduced to 48 km/h.

Truck speed turns out to be quite variable: the truck computer records show that trip times typically vary with a standard deviation of 4%. This factor alone makes it difficult to predict total shift times closer than about half an hour.

SLACK TIME

For the purposes of this study, slack time is the difference between the permitted length of a driver's shift and its actual length. Slack time is also known as *undertime*. There is no direct cost associated with slack time, but it *is* an indication that the number of trucks might be reduced. Reducing slack time *without* reducing the number of trucks brings no real benefit.

Under New Zealand law (Transport Act, section 70B), a driver may be on duty no more than 14 hours a day including rest breaks, and including no more than 11 hours driving.

The Act is a little vague, and at the time of the studied schedules, it was generally believed that the driver had to take one half hour rest break once he had driven for a total of five and a half hours (330 minutes). A subsequent legal precedent[2] required the driver to take a rest break after every five and a half hours *work*, thus requiring *two* breaks in a 14 hour shift. Pan Pac was using the two-break policy even before the Oamaru ruling. This still leaves 780 minutes of shift time for loading, driving, weighing and unloading activities.

The half hour rest break must be *uninterrupted*, so a 40 minute loading operation cannot be used as a rest break if the truck has to be repositioned half way through. Pan Pac does not allow rest breaks to be taken during loading and unloading.

In this study, Pan Pac's policy was interpreted as follows[3]. As we understood it, the law required a single rest break after

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[2] *Police v Neil Raymond Hislop* (DC, Oamaru 15th February 1994)

[3] Remember, the manual schedules were created *before* the Oamaru precedent, and the computer programme was written in the same spirit.

330 minutes total driving, but since Pan Pac wanted *two* rest breaks, these would presumably taken at the 220 and 440 minute marks. Hence:

- if there was less than 220 minutes driving, no rest break was required
- if the driving time lay between 220 minutes and 440 minutes, only one rest break was needed
- shifts containing over 440 minutes driving required two rest breaks.

The computer used these rules to check the validity of the "manual" schedules. The vast majority of truck shifts during the study period came within the 840 minute legal shift length, but there were exceptions. Such overlong shifts are not always what they seem, however. The true shift length may be shorter than calculated by the computer for a number of reasons. Allowances should be made for:

- quicker than usual loading and unloading
- on carts[4]
- good road conditions leading to shorter travel times
- slight differences between reality and the mathematical model.

Nevertheless, any shift calculated at over 1000 minutes (including rest breaks) must be regarded as invalid.

[4] Loads that are loaded up today but not actually delivered until tomorrow. Pan Pac records show this as a complete delivery made today. Fortunately, on carts are very rare.

SCHEDULING EFFICIENCY

Defects in the Manual Schedules

Before attempting to create an optimal schedule, the computer first scrutinises Pan Pac's manual schedule to make sure all the shifts are valid. Occasionally, the computer model identified some of the manual shifts as impossible or illegal, or both. Such a shift may be identified as invalid because:

- it really is illegal or impossible
- it can be done legally, but only if the driver is lucky (that is, light traffic and no delays)
- the model contains defects (all models do)
- the researcher has made a mistake when typing the schedules into the computer
- the researcher has typed correctly but misinterpreted Pan Pac's records.

In many cases it is not possible to determine which explanation is correct, so the simple solution is just to remove the offending shift from the manual schedule, leaving a reduced schedule for the computer to compete with. On shift length, Pan Pac has been given the benefit of the doubt: shifts are only removed if they exceed 1000 minutes. The computer schedules were limited to 840 minutes.

Time window (business hours) violation was *never* considered grounds for rejecting a manual shift. All the manual shifts must have satisfied the true time windows or the logs would never have been delivered in the first place.

Creating Computer Schedules

This is not the place for a detailed exposition of the mathematical techniques used for creating computer schedules. Nevertheless, some mention must be made of the general strategy. A number of techniques were tried, but only the most effective one will be described here.

The best scheduling method was an *improvement method*: given a log truck schedule, the computer rearranged it to produce a cheaper or "more legal" schedule. The computer took the "manual" schedule as a starting point and made repeated improvements until no further progress could be made.

A large part of the computer programme was dedicated to calculating the cost of a schedule. The cost of a schedule was calculated as the sum of the cost of each truck's tour of duty. The cost of a tour was calculated from running and standing costs as described earlier. In the absence of queueing, each tour can be costed independently.

If the model is expanded to include queueing, this independence is lost. However, the cost and legality of a complete schedule can still be assessed by *simulation*.

All tours are tested for legality before being costed, and penalties are imposed for missed time windows, over-long shifts, and loads assigned to trucks that cannot carry them. These penalties were very large (over \$10,000), which made illegal schedules very expensive. Once the computer obtained a legal schedule, the penalties ensured that no further illegal schedules were produced.

The schedule was improved by considering a large number of small changes to the tour For instance, if a load is transferred from one truck's tour to another, any savings can easily be calculated:

$$\begin{aligned} saving = cost(tour\_1) + cost(tour\_2) \\ - cost(tour\_1 - one\_load) \\ - cost(tour\_2 + one\_load) \end{aligned}$$

The alterations considered were:

Transfers The transfer of one load from one truck to another (described above)

Swaps Swapping a load from one truck with a load on another truck

Matchings Dividing every tour into two parts and then joining the parts together in the best possible way.

These techniques are more fully covered in (Robinson, 1995).

Manual Despatching and Computer Schedules

The "manual schedules" produced by Pan Pac are in fact a record of *despatch* decisions. The human despatcher is operating in a very different environment from that of a retrospective computer schedule:

- the computer can only *estimate* where any truck would have been at a given time; the despatcher *knows* where each truck is
- the computer does not have to deal with random events that disrupt a despatcher's plans
- the despatcher may have a greater choice of logs; the record only shows what logs *were* delivered, not what logs were *available* for delivery

- the computer knows in hindsight exactly what logs it has to work with; the despatcher has to work with imperfect knowledge.

Since there is no way of telling what the despatcher knew and when he or she knew it, it is impossible to assess the quality of his or her decisions. What looks like a mistake in hindsight might well have been the best decision at the time.

Schedule Comparison

On August 13, 1993, Pan Pac delivered 102 loads of logs using 31 trucks at a cost of $32,050 (Table 6). The best computer schedule delivers the same loads using 30 trucks at a cost of $31,047, for a saving of $1,004.

As can be seen from Table 6, some aspects of the schedule are identical in both cases. The *loaded distance* is independent of the schedule used because each load has a fixed destination, and the distance from the forest to the customer remains constant. The rest time depends on the number of trucks but also on the schedule structure; in this instance, only one 30 minute rest break was saved. The real savings come from reduced *slack time* (using fewer trucks) and from smaller *unloaded distance* (better back loading).

Table 7 shows an example where Pan Pac's despatching has been 98.8% efficient. The computer schedule makes very slight gains in back loading, but because this is not enough to save a truck, the slack time is actually *increased*.

Table 6 - Schedule Comparison for August 13, 1993

Measures		Schedule		Improvement	
		"Manual"	Computer	Absolute	Percent
Total loads carried		102	102		
Total driving time	*(minutes)*	15 260	14 879	381	2.5 %
Total standing time	*(minutes)*	5 826	5 826	0	0.0 %
Total rest time	*(minutes)*	1 590	1 560	30	1.9 %
Total slack time	*(minutes)*	3 794	2 935	859	22.6 %
Total shift time	*(minutes)*	26 470	25 200	1 270	4.8 %
Total overshift	*(minutes)*	430	0	430	100.0 %
Total loaded distance	*(km)*	7 705	7 705	0	0.0 %
Total unloaded distance	*(km)*	6 830	6 413	417	6.1 %
Total distance	*(km)*	14 535	14 118	417	2.9 %
Total running cost	*($)*	14 576	14 179	397	2.7 %
Total standing cost	*($)*	17 474	16 868	607	3.5 %
Total cost	*($)*	32 050	31 047	1 004	3.1 %
Average speed	*(km/h)*	57	57	0	
Loaded running		53.0 %	54.6 %	1.6 %	
Trucks used	*(trucks)*	31	30	1	

Table 7 - Schedule Comparison for August 12, 1993

Measures		Schedule		Improvement	
		"Manual"	Computer	Absolute	Percent
Total loads carried		86	86		
Total driving time	*(minutes)*	14 216	13 919	297	2.1 %
Total standing time	*(minutes)*	4 952	4 966	-14	-0.3 %
Total rest time	*(minutes)*	1 560	1 500	60	3.8 %
Total slack time	*(minutes)*	2 133	2 295	-162	-7.6 %
Total shift time	*(minutes)*	22 861	22 680	181	0.8 %
Total overshift	*(minutes)*	181	0	181	100.0 %
Total loaded distance	*(km)*	7 634	7 634	0	0.0 %
Total unloaded distance	*(km)*	6 114	5 795	319	5.2 %
Total distance	*(km)*	13 748	13 429	319	2.3 %
Total running cost	*($)*	13 816	13 480	336	2.4 %
Total standing cost	*($)*	15 209	15 196	13	0.1 %
Total cost	*($)*	29 025	28 676	349	1.2 %
Average speed	*(km/h)*	58	58	0	
Loaded running		55.5 %	54.6 %	0.9 %	
Trucks used	*(trucks)*	27	27	0	

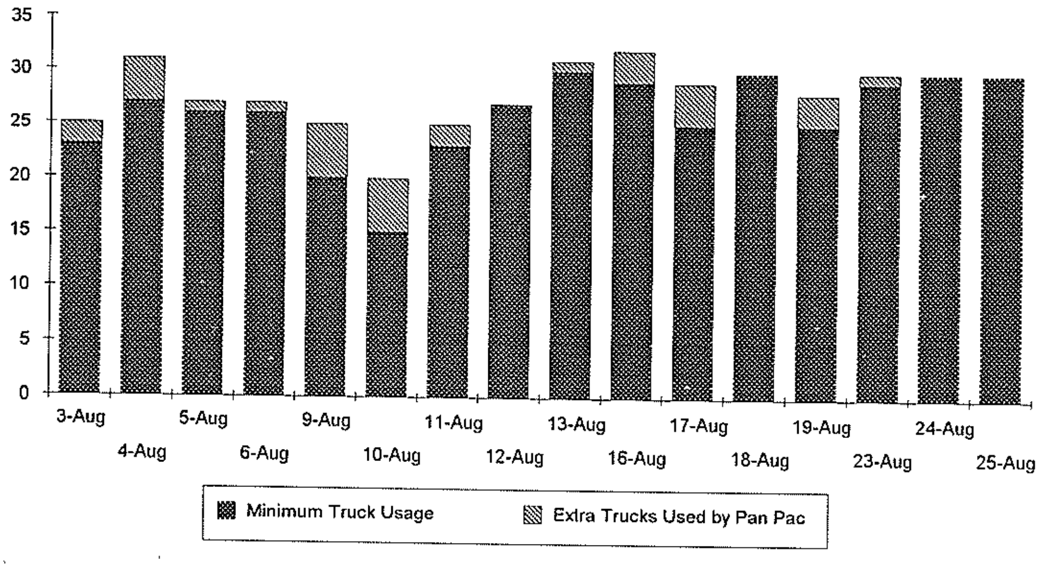

Figure 3 - Truck scheduling efficiency as shown by number of trucks used

Overall Efficiency

Altogether 16 "manual" schedules were considered. The main savings found by the computer were reductions in slack time, which represents a decrease in the number of trucks used. Figure 3 shows the number of trucks used and saved. Note, that any reduction below 24 trucks is not a true saving because Pan Pac is committed to paying for its base fleet even when some of the trucks are not used. The dramatic reduction from 20 to 15 trucks on August 10, is of no practical importance: Pan Pac already had four trucks standing idle, and there is no point in parking up another five! (The dip in the graph from August 9 to 11 was due to bad weather.)

For four of the days in the study (August 3, 9, 10 and 11, 1993), the computer was able to schedule the loads using fewer than 24 trucks. As mentioned above, this represents a false saving, since the standing cost of the base fleet cannot be reduced. These four days must therefore be excluded from consideration. The remaining 12 days all used at least 24 trucks, and the results are summarised in Table 8. The total cost of the computer schedules was 4.2% less than that of the manual schedules. This means that Pan Pac's scheduling efficiency is estimated at 95.8%.

Table 8 - Schedule comparison averaged over 12 days[5]

Measures		**Schedule**		**Improvement**	
		"Manual"	**Computer**	**Absolute**	**Percent**
Total loads carried		83	83	0	0.0 %
Total driving time	*(minutes)*	13 859	13 506	352	2.4 %
Total standing time	*(minutes)*	4 921	4 914	7	0.1 %
Total rest time	*(minutes)*	1 470	1 463	7	0.5 %
Total slack time	*(minutes)*	3 617	2 447	1 170	32.3 %
Total shift time	*(minutes)*	23 867	22 330	1 537	6.4 %
Total overshift [6]	*(minutes)*	277	0	277	100.0 %
Total loaded distance	*(km)*	7 223	7 223	0	0.0 %
Total unloaded distance	*(km)*	6 131	5 750	381	6.2 %
Total distance	*(km)*	13 354	12 973	381	2.9 %
Total running cost	*($)*	13 416	13 053	363	2.7 %
Total standing cost	*($)*	15 836	14 964	872	5.5 %
Total cost	*($)*	29 252	28 017	1 235	4.2 %
Average speed	*(km/h)*	58	58	0	
Loaded running		54.1 %	55.7 %	1.4 %	
Trucks used	*(trucks)*	28.08	26.58	1.5	

[5] This does *not* include trucks and logs that occurred in manual shifts of over 1000 minutes.

[6] As discussed earlier, this figure should not be taken too seriously.

SENSITIVITY ANALYSIS

As with any mathematical model, some consideration must be given to sensitivity: how sensitive is scheduling efficiency to assumptions made in the model?

Sensitivity to Truck Speed

The most obvious consideration is truck speed. After all, if the trucks can be made to travel faster, they will get more work done in a day. If the speeds used in the model are too slow, then the computer schedules will be more expensive than necessary, making the manual schedule look better than it really is. On the other hand, if the speeds used in the model are too high, it would be the computer that gets an unfair advantage.

This effect is moderated by the fact that manual schedules are not taken entirely on trust. If the speeds used in the model are too low, then the calculated shift times for the manual schedules will be too high, and some may be forced over the 1000 minute limit. Likewise, if the speeds used in the model are too high, some of the manual shifts will appear valid when in fact they should be discounted.

Some extra computer schedules were created to determine which of these effects predominates. Only one day's loads were considered (Table 9).

Table 9 - Sensitivity of calculated efficiency to speed assumptions

		10 % Slower	**Standard Speed**	**10 % Faster**	**20 % Faster**
Average Speed *(km/h)*		49	54	59	66
Invalid Shifts		7	2	1	0
Loads from Valid Shifts		75	94	97	101
Trucks Used	Manual	24	29	30	31
	Computer	22	26	26	25
	Difference	2	3	4	6
Cost *($)*	Manual	23 790	29 556	30 926	32 098
	Computer	22 253	27 370	28 274	28 123
	Difference	1 538	2 186	2 652	3 975
Efficiency [7]		93.5 %	92.6 %	91.4 %	87.6 %

[7] For the one day's loads under consideration.

Table 9 needs careful interpretation:

1) if the speeds used in the model are correct, then the scheduling efficiency of the 29 valid manual shifts is 92.6%

2) if the true speeds are 10% slower than assumed in the model, then the true scheduling efficiency of the 24 valid shifts is 93.5%

3) if the true speeds are 10% faster than assumed in the model, then the true scheduling efficiency of the 30 valid shifts is 91.4%

4) if the true speeds are 20% faster than assumed in the model, then the true scheduling efficiency of the 31 valid shifts is 87.6%.

Removing invalid shifts from the manual schedule has a powerful stabilising effect on efficiency calculations. The table shows that the speed can be changed by 30% and still only make a 6% difference in the calculated efficiency, not the 30% difference that might otherwise be expected.

Putting this in perspective, we are confident that the speeds used in the study are within 5% of the true value, and that consequent errors in calculated efficiency are less than 1%.

Sensitivity to Other Factors

The first draft of this report was made under slightly different assumptions:

- in the earlier draft, it was assumed that *only one* rest break would be needed, as opposed to *two*
- it was assumed that the trucks would run 5% slower than the current estimate
- shifts were regarded as invalid if the shift time *excluding* rest breaks was over *900 minutes*, while present policy is to exclude shifts exceeding *1000 minutes including* rest breaks
- all 16 days of the study were included in the original summary, but adjustments were made to allow for schedules using fewer than 24 trucks.

The calculated efficiency under these conditions was 94.5%. This is remarkably close to the result of 95.8% calculated here. This shows that the scheduling efficiency calculation is fairly robust.

CONCLUSIONS

The project has achieved its aim of placing a dollar value on the quality of Pan Pac's manual despatching, and in locating its most important weaknesses. Within the limitations of the study, we conclude:

- **the difference between Pan Pac's transport costs and the optimal costs during the 12 days used in the summary was less than $1250/day on average. This represents a saving *to the industry* of $300 000 per year**
- **Pan Pac's despatching efficiency during the period in question was calculated at 95.8%. This figure is probably accurate to about 1%**

- **the majority of the potential savings comes from reducing the number of trucks used; up to 1.5 trucks a day might be saved, worth around $900 per day**

- **reducing the number of trucks will not be easy, as this requires perfect information and perfectly predictable trucks, drivers, loaders, weighbridges and customers**

- **attempts to improve the loaded running percentage might save about $350 per day.**

It remains an open question how much of the estimated $1,250 a day could actually be saved by computer-aided despatching. Retrospective analysis is far removed from real-world despatching with its deadlines and uncertainties.

There is no doubt that computer-aided despatching could be made fast enough to deal with the deadlines, but uncertainties can only be dispelled by *timely* and *accurate* information.

It is not enough to buy a despatching programme; it is necessary to review policy, procedures, and communications for the whole system from the forest to the customer. Even then, the computer despatcher cannot beat the "computer schedule" used in this study, because the computer schedule works with the benefit of hindsight, that is, with all the information the despatcher *could have had* and more.

The calculated savings are savings to the industry, not to the company. Where a company relies heavily on contract operators, it would take many months of improved despatching before the truck operators could be persuaded to accept a lower haulage rate.

This analysis has not included any benefits due to improved customer service, integration with other computer systems, and reduced staffing costs.

In this study, computer-aided scheduling has been used as an *auditing* tool only. At present, LIRO has no plans to produce a usable despatching aid. However, when requested LIRO will *advise* its members on this subject.

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The costs stated in this report have been derived using LIRO costing procedures. They are an indicative estimate and do not necessarily represent the actual costs for this operation.
