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Operational Forest Harvest Scheduling Optimisation

A mathematical model and solution strategy

by Stuart Anthony Mitchell

Supervised by Professor David Ryan and Dr Chris Goulding

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of
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Abstract

This thesis describes the Operational Harvest Scheduling (OHS) problem and develops an algorithm that solves instances of the problem. The solution to an OHS problem is an Operational Harvest Schedule (OHS).

An OHS:

- assigns forest harvesting crews to locations within a forest in the short-term (4-8 weeks);
- instructs crews to harvest specific log-types and allocates these log-types to customers;
- maximises profitability while meeting customer demand.

The OHS problem is modelled as a Mixed Integer Linear Program (MILP). The formulation given in this thesis differs significantly from previous literature, especially with regard to the construction of the problem variables. With this novel formulation, the problem can be solved using techniques developed in previous work on aircraft crew scheduling optimisation (Ryan 1992). These techniques include constraint branching and column generation.

The concept of relaxed integer solutions is introduced. A traditional integer solution to the OHS problem will require harvesting crews to move between harvesting locations at the end of a week. However, a relaxed integer solution allows crews to move at any time during a week. This concept allows my OHS model to more effectively model the practical problem.

The OHS model is formulated for New Zealand and Australian commercial forestry operations, though the model could be applied to other intensively managed production forests. Three case studies are developed for two companies. These case studies show improvements in profitability over manual solution methods and a significant improvement in the ability to meet demand restrictions. The optimised solutions increased profit (revenue less harvesting and transportation costs) by between 3-7%, while decreasing the total value of excess or shortfall logs by between 15-86%.

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List of Acronyms

- AC Australian Company One of the two companies that provided case studies.
- B&B Branch and Bound A technique for finding integer solutions from a RLP.
- CA Crew Allocation The decision to place a particular crew in a harvest unit in a period, also the constraints that model this decision in the OHS formulation.
- CGA Column Generation Algorithm The sub-problem in Column generation.
- DP Dynamic Program A technique used to solve some types of OR problems.
- FOLPI..... Forestry Orientated Linear Programming Interpreter Estate modelling tool created at *forest research* and commonly used in NZ.
- forest research* . New Zealand Forest Research Limited The New Zealand Crown Research Institute responsible for research in forestry.
- FSC Forest Stewardship Council An organisation that encourages sustainable forestry.
- GIS Geographical Information System
- GSPP..... Generalised Set Partitioning Problem An extension of the SPP.
- GUB Generalised Upper Bound A term used to refer to a type of constraint common in scheduling problems.
- IP Integer Program An extension of an LP which only contains integer variables.

- LP..... Linear Program A technique used to solve some types of OR problems.
- MARVL..... Method of Assessment of Recoverable Volume by Log-type Standing inventory tool created at *forest research* and commonly used in NZ.
- MILP..... Mixed Integer Linear Program An extension of a LP to include integer variables.
- NFP..... Network Flow Problem A special subset of LP problems that will give naturally integer solutions.
- NZ..... New Zealand
- NZC..... New Zealand Company One of the two companies that provided case studies.
- OHS..... Operational Harvest Scheduling Short term scheduling of forestry crews within a forest with production allocation.
- OHSA..... Operational Harvest Scheduling Algorithm The algorithm that solves the OHS problem.
- OR..... Operations Research The science of better.
- PLE..... Probable Limits of Error The confidence interval of an estimate expressed as a percentage of the mean.
- PT..... Production/ Transportation The constraints that model the linear transportation, and production decisions in the OHS formulation.
- RLP..... Relaxed Linear Program The problem resulting when the integer restrictions on the MILP are removed, and the MILP solved as a standard LP problem.
- RMP..... Restricted Master Problem The master problem in Column generation.
- SED..... Small End Diameter The diameter of the smallest end of a log.
- SPP..... Set Partitioning Problem A special type of IP.

ZIP Zero-one Integer Programming A programming framework developed at the University of Auckland (Ryan 1980), for the solution of large scheduling problems.

