

Integrated Timber Allocation and Transportation Planning in Ireland

G. Williamson¹
M. Nieuwenhuis
*University College, Dublin
Belfield, Ireland*

ABSTRACT

Coillte Teoranta, the Irish Forestry Board, was established as a forestry company in 1989, with a mandate to operate in forestry and related activities in a commercial manner. The company took over the assets of the state Forest Service and now owns and manages approximately 400,000 ha of forest. Coillte harvests and sells timber to the private wood processing industries in Ireland.

Coillte harvested approximately 1.4 million m³ of timber in 1990. By 2010 this annual harvest volume will increase to 3.5 million m³. In order to manage the harvesting and transportation operations efficiently, a national timber sales allocation procedure was developed by the Forestry Department of University College, Dublin. The procedure uses Coillte's databases on harvest volumes, subdivided into supply categories; on mill demands, specified by demand categories; and on the national transportation network, including road, rail and water transport modes.

The developed operational procedure was used as a decision-making tool during the allocation of the 1991 sales volumes. A comparison of the actual versus the optimized 1990 allocation strategy identified opportunities for large-scale savings. In addition to its main function as a decision-making tool for the annual sales allocation, the model has been used for other strategic and tactical planning analyses, such as the influence of new mill location on transport costs, the impacts of a timber processing industry rationalization programme on the industry as a whole and on individual mills, the feasibility of timber transport by rail, the selection of suitable ports for timber export, and the impact of road construction and improvement programmes on national timber transport strategies. The model has

been successfully linked with the company's ARC/INFO Geographic Information System which extends the post-allocation analysis and interpretation capabilities, and combines the output with existing information systems. A further integration of the procedure in the management decision-making processes in the company will result in increased cost saving opportunities.

Keywords: *timber allocation, transportation planning, plant location, network analysis.*

INTRODUCTION

As the value of timber is a residual one, the minimization of the total cost of getting timber into a mill yard will have a major impact on the profitability of the forest industry. This overall cost is composed of stumpage, harvesting and transport costs. As has been found in many studies, both in Ireland and abroad, the transport cost contributes up to 25% of this total raw material cost [4, 5], in the case of pulpwood even up to 40 per cent [7]. Both in the case where timber is sold standing, and where it is sold at the mill gate, reducing the transport cost will result in higher stumpage payments to the selling agent, in this study Coillte Teoranta, the Irish Forestry Board.

One important factor in the effort to reduce transportation costs is the optimal linkage of forests and mills. The determination of the appropriate mill destination for each cubic metre of timber for sale in a forest, known as timber sales allocation, will have a major influence on the overall transport distances and, as a result, on transport costs.

Two developments have emphasized the importance of efficient timber sales allocation procedures. First, the change in 1989 of the state Forest Service into a commercial semi-state company, Coillte Teoranta. This new company has targeted the areas of harvesting, transportation and processing as possible profit-generating operations, and wants to take more control of these production processes in order to increase its profitability. One specific area where efficiency improvement possibilities have been identified is in the transportation of raw material from forests to processing locations. Both the reduction of transport distances, and the allocation of specific products to the appropriate mills, should be targeted in any cost reduction strategies.

¹The authors are, respectively, Newman Scholar in Forestry and Lecturer, Department of Forestry.

Secondly, as a result of past planting and management schedules, the annual timber harvest volume in Coillte's forests will increase from 1.4 million m³ in 1990 to 3.5 million m³ in 2010. This rapid increase necessitates improved planning and scheduling procedures in order to benefit fully from the improved flexibility and expanded processing alternatives which this expansion offers. Existing industries will increase production capacities and new operations will be introduced. In order to ensure a structured and organized approach to this expansion and introduction of new processing capacity, planning tools are required to examine the impacts of various strategic decisions both on the industry as a whole and on individual mills. In order to manage the increased and more complex timber flows efficiently and effectively, new integrated management procedures are required. This paper presents an overview of the development and use of an integrated timber allocation decision support system for operational and strategic planning.

PROBLEM DEFINITION

When examining Coillte's timber sales plan for 1991, the importance of the development of a systematic allocation procedure becomes apparent. The sales plan consists of 2,674 sales in 245 forests, each sale consisting of up to 6 species and 5 assortments, giving a possible total of 30 supply categories per sale. Taking only the 20 largest sawmills and wood processing plants into account, each with up to 10 demand categories, the task of allocating the volumes in the supply categories of each sale according to the specific demands of the mills in each demand category in a cost effective manner, becomes impossible without the use of computerized Operations Research (OR) techniques [2].

The objective of the procedure to be developed had to be the optimal allocation (i.e., minimum transportation cost allocation) of the timber in the forests to the processing locations, constrained by supply and demand restrictions for each of the product categories considered. Additional constraints may have to be introduced in relation to restrictions imposed by the transportation network. A wide range of factors has to be considered in trying to optimize the transportation aspects of forest operations. One important cost factor involved is the product of volume transported times the transport distance (i.e., m³.mile or m³.kilometre). By minimizing the sum of all m³.kilometre values for all allocated products in all sales, the main factor deter-

mining overall transport cost has been minimized. The problem can be stated mathematically as follows:

Minimize:

$$\sum_p \sum_{(i,j) \in A} h_{ijp} f_{ijp}$$

Subject to:

$$\sum_{\{i|(i,j) \in A\}} f_{ijp} - \sum_{\{k|(j,k) \in A\}} f_{kjp} \geq d_{jpp} \quad \text{for all nodes } j$$

$$\sum_{\{i|(i,j) \in A\}} f_{ijp} - \sum_{\{k|(j,k) \in A\}} f_{kjp} \geq s_{jpp} \quad \text{for all nodes } j$$

$$l_{ijp} \leq \sum_p f_{ijp} \leq u_{ijp} \quad \text{for all } (i,j) \in A$$

Where:

A is the collection of arcs from node i to node j , for all i and j

(i,j) is a directed arc from node i to node j

h_{ijp} is the hauling distance on arc (i,j) for product category p

f_{ijp} is the flow on arc (i,j) for product category p

s_{jpp} is the supply at node j of product category p

d_{jpp} is the demand at node j of product category p

l_{ijp} is the minimum feasible flow on arc (i,j) of product category p

u_{ijp} is the capacity of a rc (i,j) for product category p .

One important assumption made throughout this study was that the segregation of timber sales into the different supply categories was always feasible. At the moment, this segregation is only possible in sales which are harvested by Coillte or by Coillte-controlled contractors. But given the intention of the company to increase its involvement in timber harvesting and transportation operations, the assumption does not impose a major restriction on the applicability of the results of the study, and allows for the use of more efficient computer algorithms, an important factor to consider when dealing with large-scale network analysis problems [1].

THE TIMBER SALES ALLOCATION MODEL

The model will assist in the allocation of Coillte Teoranta's annual timber sales, with the objective to minimize overall transport distance, constrained by supply, demand and network restrictions. The model consists of three parts: the Input procedure, the Allocation procedure, and the Output procedure [9,

10]. See Figure 1 for the schematic model structure. Each of the three procedures is briefly outlined below.

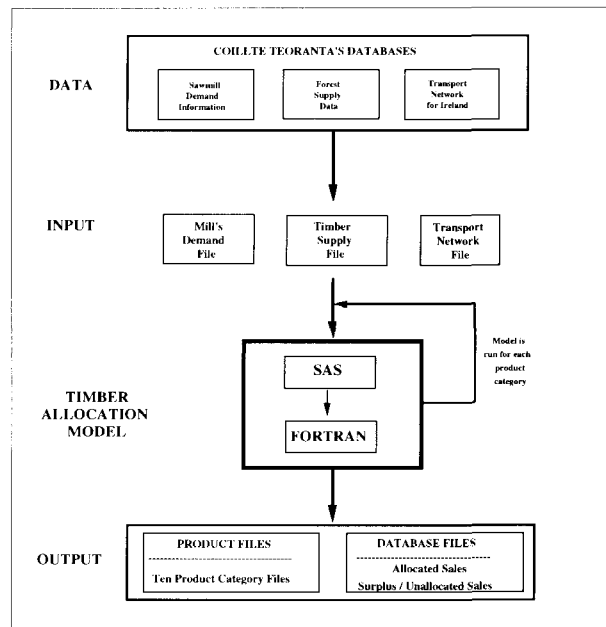


Figure 1. Schematic diagram of the timber sales allocation model.

The Input Procedure

Mill demand data, sales supply data and transportation network data are collected and modified to form the database of the allocation procedure. Corresponding product supply and demand categories are separated and quantified, the road network is updated and network restrictions are identified. The sales data file for 1991 consists of 2,674 sales in 245 forests with each containing volumes for up to 10 supply categories. The mill demand file contains demand information for the largest 20 sawmills and wood processing plants, and 8 export contracts, each with up to 10 demand category volumes. The network consists of approximately 7,600 links and 3,000 nodes. Both the road and rail networks are included. The model has been integrated with the ARC/INFO Geographic Information System. This allows the direct extraction of timber supply, mill demand and transport network data from GIS databases.

The Allocation Procedure

The optimal allocation of the timber is determined by computer, using network analysis procedures [3]. The cost minimization process consists of two steps. First, the "shortest route" between forests

(supplies) and processing locations (demands) has to be established. In the case where payment is purely based on travel distance, the shortest route should only take road length into account, but other possibilities, such as the inclusion of road standard and travel time, can be examined using a combination of distance, travel speed and road class data. Second, the optimal allocation of the timber supply from the forests to the mills, using the shortest routes as determined above, is established. The allocation is determined for each product supply and demand category in a predetermined order. This is to allow for the use of more efficient computer algorithms and the limited transfer of excess supply or demand to subsequent categories. At the current level of product segregation, 10 supply and demand categories are distinguished. These are presented in Figure 2. The allowable transfers of excess supply and demand are also indicated.

If more categories are required, because of further mill specialization or the introduction of new processing techniques, these can be accommodated if within the level of detail of the sales databases. A total of 66 sawmills are included in the mill data base, and any subset of these can be selected for inclusion in the analysis. Both mainframe and micro computer implementations of the network analysis software have been used during the development of the allocation model [6].

The Output Procedure

Customized output procedures organise the standard output formats into output listings and database files for further analysis and printing. Reports giving any level of required detail can be generated, from overall summaries down to the precise route to the mill of each allocated cubic metre from a supply category of a particular sale in a specific forest. The integration of the model with Coillte's GIS permits the allocation results to be presented graphically. It also extends the post-allocation analysis and interpretation capabilities and further integrates the output with existing spatial databases. For example, a direct comparison of actual and optimal haulage patterns is possible and the areas of variance can be easily identified and quantified.

RESULTS

Although the timber allocation model was originally developed to assist in the cost efficient allocation of Coillte's annual timber sales, the model has

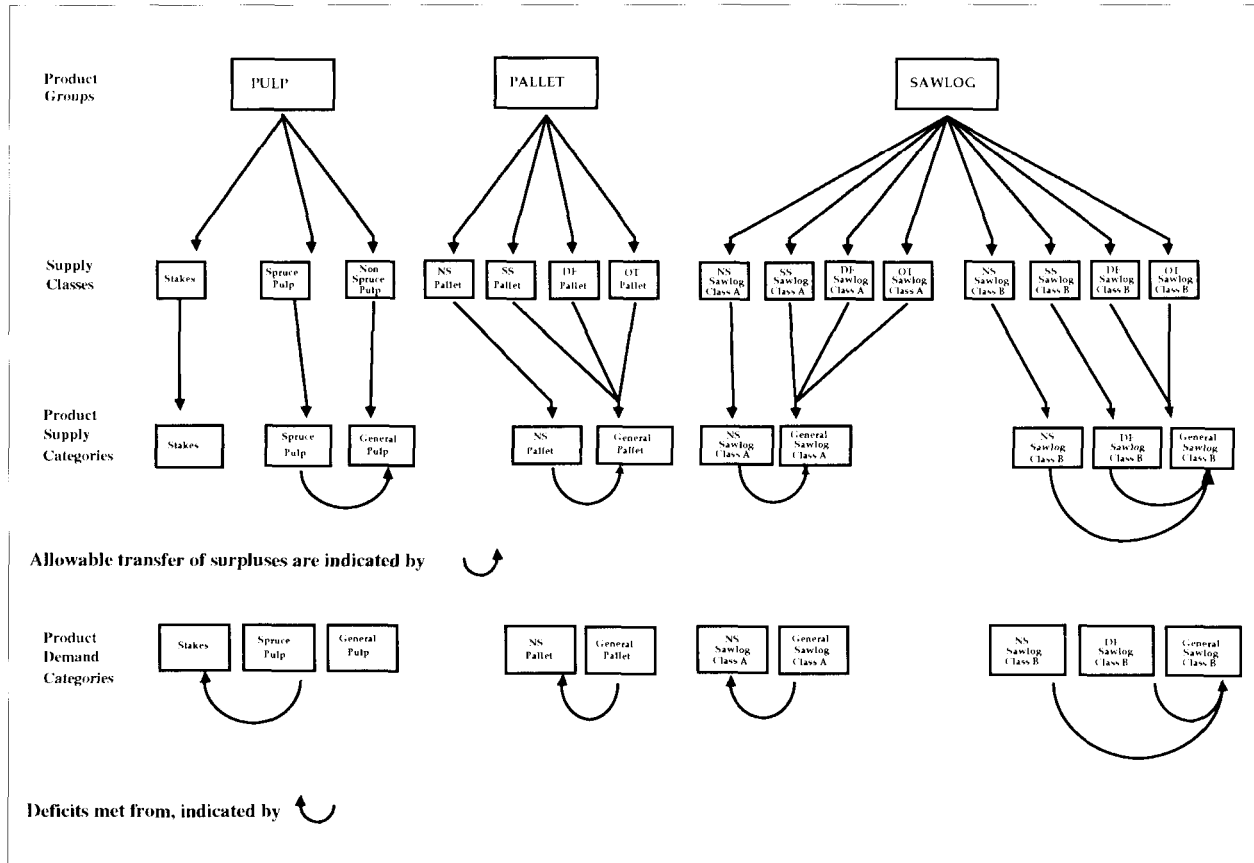


Figure 2. Product supply and demand categories. (NS = Norway spruce, SS = Sitka spruce, DF = Douglas fir, OT = Other. Class A = Average tree size $\leq 0.35 \text{ m}^3$, Class B = Average tree size $> 0.35 \text{ m}^3$)

also been effectively applied to long-term strategic planning problems. The results of a number of applications of the model, both for operational and strategic planning, are presented below.

Use of the Model for Operational Planning

Comparison of actual and optimal timber allocation strategies for 1990

To quantify the potential reduction in total transport distance and associated transport cost obtainable by using the timber allocation model, the “actual” and “optimal” allocation strategies for 1990 were examined. Summary results of the 1990 sales allocation, both for transport distance and for transport cost, are presented in Figures 3 and 4. A reduction in average transport distance from 79.2 km to 48.8 km was shown to be feasible, a 38% improvement. This corresponds to a possible reduction in transport cost of up to IRE1,000,000. The associated reductions in haulage cost for each product

are presented in Figure 4. It has to be emphasized that the “optimal” allocation is optimal only in relation to the *transport distance*. Additional operational and tactical constraints such as timber quality, machine scheduling and site access will make it impossible to implement this allocation strategy without modifications. The influence of these modifications on the overall cost structure can however be quantified and, as a result, informed management decisions with respect to the company’s sales allocation and transport policy can be made.

Selection of suitable ports for export sales

Because of an over-supply of small timber, Coillte currently exports approximately 120,000 m^3 of pulpwood per annum. Ports with their timber handling facilities and capacities were included in the network and an analysis performed on the best possible sales allocation and port selection to facilitate a range of export volumes and destinations.

Rail transportation of round timber

The use of rail transport for long, distance movement of timber has been studied. The rail network, including loading and unloading facilities and linkages with the road network, has been integrated in the overall transport network. Because of uncertainties in relation to handling and associated costs, and the present infeasibility of introducing rail transport on a viable commercial scale, this aspect of the transport analysis was not studied in depth. It is envisaged, however, that rail transport will become a viable alternative in the near future.

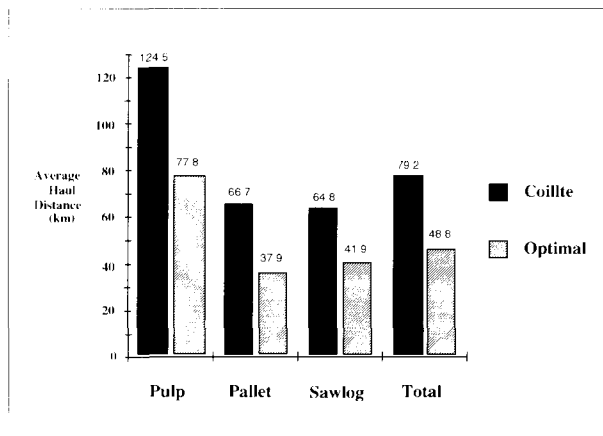


Figure 3. Actual and optimal average haul distances for 1990 allocations of pulp, pallet and sawlog. Total volume allocated is 957,534 m³.

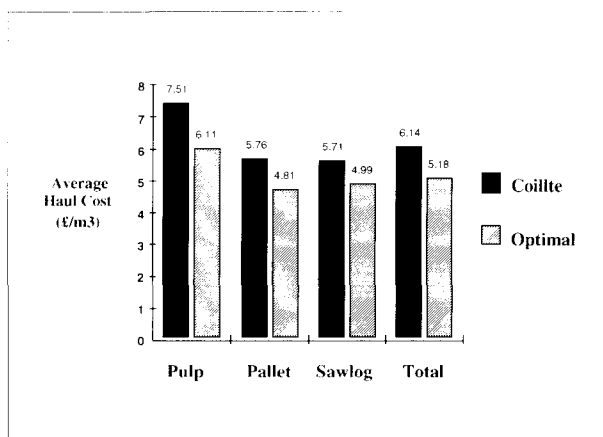


Figure 4. Actual and optimal average haul costs for 1990 allocations of pulp, pallet and sawlog.

Use of the Model for Strategic Planning

For strategic planning purposes, the level of detail does not need to be, and in most cases can not be, as great as for operational planning. Consequently the original model was modified slightly to allow it to be used to assist in strategic planning. Medium to long-term timber forecasts were used as the timber supply data as opposed to actual timber sales. Timber supply data were available by 1 kilometre National Grid coordinates, but in order to reduce the problem to a manageable size, the timber supply data were aggregated to 10 kilometre National Grid squares. The timber supply was assumed to originate from the centre of each grid square. In addition, the timber supply was subdivided into only three products, corresponding to the product groups in Figure 2 (i.e., Pulp, Pallet and Sawlog).

Location of new timber processing industries

The possible introduction of any new timber processing industry into the country will make it necessary to investigate the influence of the location of these plants on the overall timber transport situation. Although the final decision on the location of such industries depends on many factors, the inclusion of transport analysis in the decision-making process is important, both for existing industries and the planned mill. In conjunction with the spatial analysis capabilities of the GIS and with projected timber forecasts, a number of areas or zones where there will be concentrations of timber production in the future can be identified. In addition, by examining other factors such as proximity to ports and markets, a short list of possible processing plant locations can be produced. The allocation model can then be used to analyse the influence of the siting of such a plant, at each location, on the overall transport cost for the industry as a whole and on the cost changes for individual mills.

The results of an example analysis are presented in Figure 5. A hypothetical pulpwood mill with a capacity of 150,000 m³ was introduced at two possible locations: Carrick on Shannon and Foynes. The influence of the location of the new mill on both the new mill's transport cost as well as the transport cost of existing mills was analysed. The results show that Carrick on Shannon is preferred, both with respect to the average transport distance of the existing industries and of the new mill. Again it must be stressed that this type of transportation analysis is only **one** element of the total analysis required to determine the best location for a new timber processing industry.

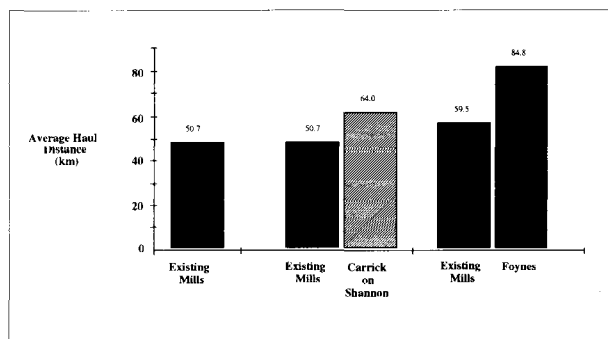


Figure 5. A comparison of average haul distances for two possible pulp mill locations.

Rationalization of the Irish timber processing industry

The volume of Coillte's annual timber harvest is increasing each year. In 1990 Coillte harvested approximately 1.4 million m³ of timber. By 2000 this annual harvest will increase to just over 2 million m³. This increase in timber supply will require a corresponding increase in processing capacity and markets for the processed timber. A study was commissioned to evaluate the state of the Irish sawmilling industry and make recommendations for its future development. The resulting report concluded that there was a strong need to develop export markets and that Irish mills are overcapitalized and underutilized. The report stressed the need to establish an Irish-based export market consortium and consolidate and rationalize the sawmilling industry, if Irish mills are going to stay competitive in the export markets [8]. Consequently Coillte and the Irish Timber Council have been co-operating in the preparation of a programme for a structured approach to the expansion and rationalization of the industry.

One aspect of this rationalization would be to increase the capacity of existing mills by going on to double shift. The first stage involved in evaluating such a strategy is to identify all the existing mills that are capable of increasing their capacity. The second stage is to determine which of the existing mills are in the best position to do so and rank them accordingly.

One element of such a study would be to examine the consequences of placing a particular mill on double shift on the timber transport distance of:

- (i) the mill itself and;
- (ii) the remaining industry.

The timber allocation procedure was used in an iterative manner to analyse the consequences of a number of scenarios from a timber transportation point of view. The principle objective of the analysis was to increase the utilization of current facilities while minimizing increases in industry haulage distances.

A hypothetical example is presented below, demonstrating the procedures involved. The mill locations and capacities used are entirely fictitious. The example consists of 10 mills with capacities varying from 20,000 - 80,000 m³ per annum. The current timber processing capacity is 13% below the forecasted supply of large sawlogs for 1995. To utilize the surplus supply, 3 mills with capacities of 80,000 m³ were identified as being capable of doubling their capacity by going onto double shift. Three scenarios were investigated:

1. Mill A with double processing capacity and remaining mills at current single shift capacity;
2. Mill B with double processing capacity and remaining mills at current single shift capacity;
3. Mill C with double processing capacity and remaining mills at current single shift capacity.

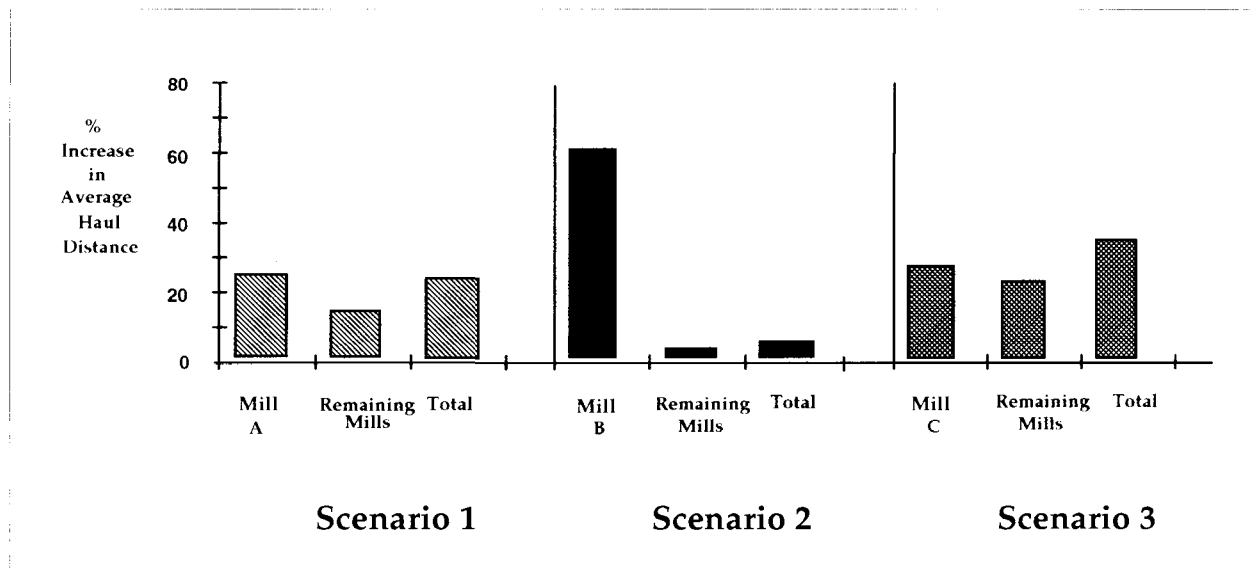
Summary results of the three scenarios are presented in Table I and Figure 6. Mill B has the least impact on the average haul distance of the remaining mills and also on the average haul distance of the industry in total. Although Mill B has the least impact on the average haul distance of the remaining mills and of the industry in total (1.9 and 5% respectively), it incurs the greatest percentage increase to its own average haul distance (61.2%). However, it still has the lowest average haul distance of the 3 possible double shift mills.

Although the rationalization of the timber processing industry depends on many different factors, the benefits of performing such an analysis are that the effects of a particular strategy can be quantified. This allows an objective informed decision, as regards transportation costs, to be made.

Integration with the GIS allows the haulage patterns of individual mills, for each scenario, to be examined. The haulage patterns resulting from the optimal allocation of large sawlogs in 1995 for the "single shift scenario" and the "mill A on double shift scenario" are presented in Figures 7a and 7b, respectively.

Table I. Impacts on average haul distances as a result of doubling processing capacity of mill A, B, or C.

Mill	Average Haul Distances (km)					
	Impact on Double shift Mill		Impact on Remaining Mills		Impact on Total Industry	
	Increase (km)	Increase %	Increase (km)	Increase %	Increase (km)	Increase %
A	23.0	25.4	7.2	12.6	15.2	24.4
B	22.0	61.2	1.3	1.9	3.2	5.0
C	27.5	27.7	12.6	22.6	21.3	34.0

**Figure 6.** Increase in the average haul distance of the double shift mill, remaining industry and total industry as a result of doubling the processing capacity of either mill A, B, or C.

CONCLUSIONS

The developed timber sale allocation procedure is capable of dealing with a variety of problems related to the optimal transportation of timber from forest to mill. Analysis options include: transport by road, rail or water; within a region, the country or including exports; to existing mills or to planned locations; for a selection of products or for the full list of supply and demand categories; using distance in the optimization or translating this to cost. In addition, sensitivity analyses can be performed on any of

the input parameters involved. The main application for which the model was developed, as a decision-making tool in the process of allocating the annual timber sales of Coillte Teoranta, has the potential to generate significant savings. The model has also been used successfully to assist in the long-term strategic planning of new timber processing plants and industry rationalization.

At present, optimization of timber sales allocation is on an annual basis. Integration of the process with timber harvest planning will allow for optimi-

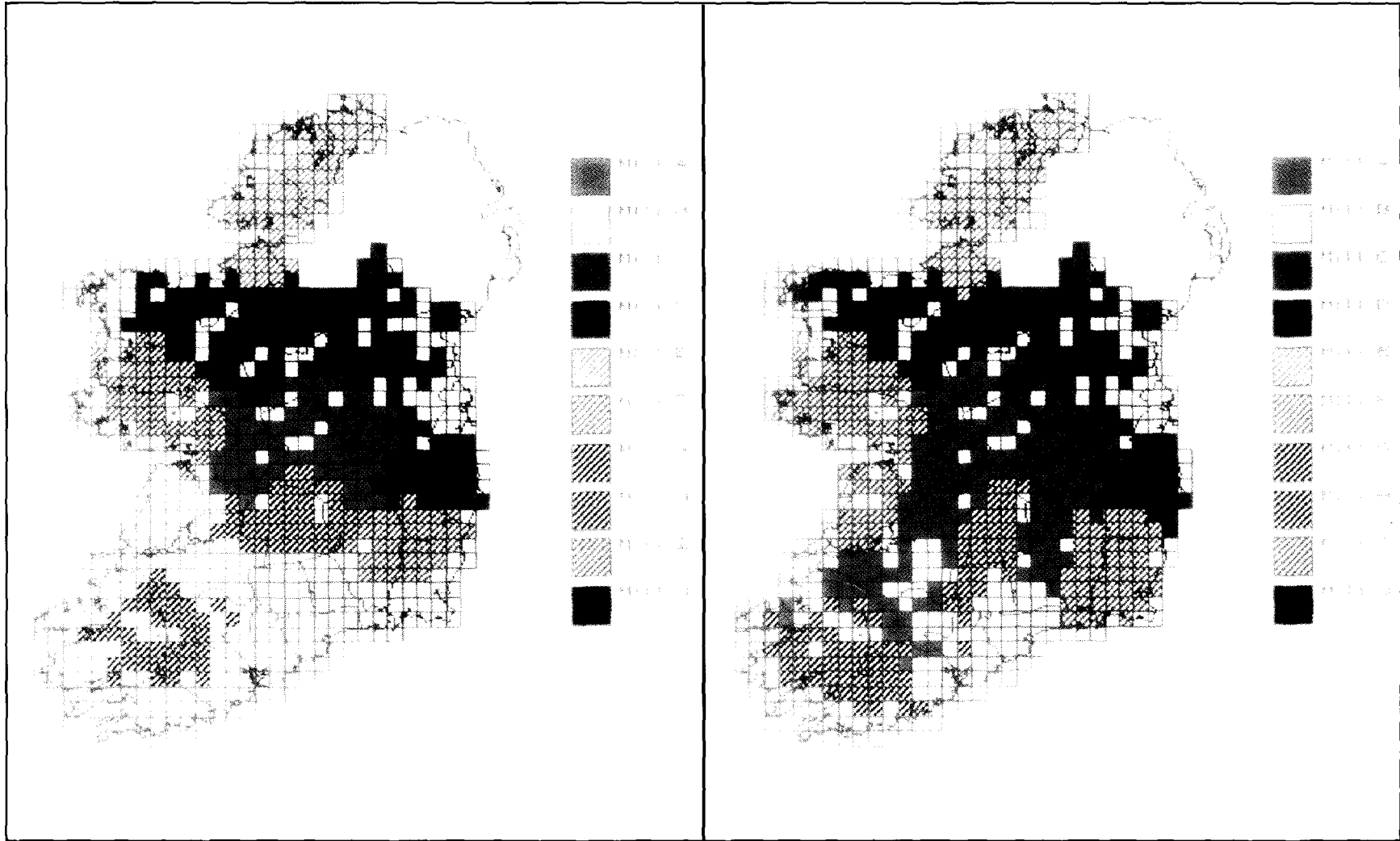


Figure 7a. Optimal allocation patterns of large sawlog in 1995 with all mills on single shift.

Figure 7b. Optimal allocation patterns of large sawlog in 1995 with Mill A on double shift.

zation over time. An important consideration in the harvest scheduling process is the spatial distribution of the timber supply and demand. A study is being embarked upon to assess the feasibility of developing a system to assist in the scheduling of timber harvests in an optimal fashion. Such a system has far-reaching implications and would impact significantly on the work practices and procedures currently in place in the company. However, it is considered that significant savings can be achieved by integrating harvest planning and timber allocation scheduling, and these would justify the retraining of personnel, and changes in organizational structures required to implement such a system.

The model has demonstrated and quantified the benefits of a computerized OR technique in operational and strategic planning. It has resulted in a large-scale investigation and analysis of the company's current timber harvest planning and timber allocation procedures. It is envisaged that the allocation model will change considerably and will be replaced by a more comprehensive timber harvest planning and timber allocation decision support system. However, the present system has indicated the potential benefits of using OR techniques, and that fact alone has made the development of the model a worthwhile and successful project.

ACKNOWLEDGEMENT

This research project was funded with a grant from Coillte Teoranta.

REFERENCES

- [1] Ford, L.R. and Fulkerson, D.R. 1962. *Flows in Networks*. Princeton: Princeton University Press.
- [2] Nieuwenhuis, M.A. 1989. *Operations Research in Forestry*. Irish Forestry. 46 (1): 51-58.
- [3] Papadimitriou, C.H. and K. Steiglitz. 1982. *Combinatorial Optimization: Algorithms and Complexity*. Prentice-Hall.
- [4] Powell, A.R. 1985. *Growing Timber for the Market*. In: *Proceedings of a Discussion Meeting*, Heriot-Watt University, Edinburgh, 29 - 31 March, 1985.
- [5] Pulkki, R.E. 1984. *Rationalization of Wood Delivery by Road, Railway and Water in South-Eastern Finland*. In: *Proceedings of the Council on Forest Engineering/IUFRO (Division 3) Symposium*. University of Maine at Orono, U.S.A.
- [6] SAS Institute Inc. 1988. *SAS/OR User's Guide*, Release 6.03 Edition. Cary, NC: SAS Institute Inc.
- [7] Schreuder, D.I. and T.J. Corcoran. 1965. *Distribution Patterns of Trucked Pulpwood in Eastern-Central Maine*. Bulletin 630, Maine Agr. Exp. Station, University of Maine, Orono, USA.
- [8] Simmons, 1991. *The Irish Timber Industry — An Export Development Plan for the 1990's*. Prepared for Coillte Teoranta, Irish Timber Council, Industrial Development Authority and Coras Trachtala. Simmons Strategic Services Division, Vancouver, British Columbia, Canada.
- [9] Williamson, G.P. and M.A. Nieuwenhuis. 1991. *Timber Sales Allocation Model User's Manual*. Internal publication, Department of Forestry, University College, Dublin, Ireland.
- [10] Williamson, G.P. 1991. *Development of a Timber Allocation Procedure*. Master's Thesis, Department of Forestry, University College Dublin, Ireland.