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Using Network 2000 Program for Transportation Planning of Forest Products*

Hande E. Süslü**

Southern University and A&M College, Urban Forestry Department, Baton Rouge, 70813 LA, USA.

Abstract

The construction and maintenance of forest roads are the activities that require the highest financial investment in the extraction of forest products. In addition, the cost of transporting forest products from landing to storage area can be significant proportion of the total extraction cost. For this reason, forest engineers are obliged not only to reduce the cost of road construction and maintenance, but also to prepare the most appropriate transportation plan to minimize total costs. Computer aided models can be used to solve complex transportation problems that require the evaluation of many alternative routes and selection of the alternative with least cost. In this study, the Network 2000 program based on the shortest path algorithm was used in transportation planning of forest product, and then the solution capacity of the method was examined in a sample application. As a study area, two Forest Enterprise Chiefs (FECs) of Paşalar and Sarnıç were selected from Mustafakemalpasa Forest Enterprise Directorate (FED) in the border of Bursa Forest Regional Directorate. The transportation cost of the road sections, forest product types, location of landing and forest depots were entered into the Network 2000 program after being digitized with ArcGIS 10.2 software. In the solution process, firstly, the route that minimized the transportation cost was investigated, and then, the route with the maximum net profit was determined by taking the sale prices of forest products into consideration. According to results, the transportation cost mostly depends on the transportation time, hourly truck cost and load capacity of the truck.

Keywords: Mechanized harvesting, harvester, time and motion study, productivity

1. Introduction

In The forest products transportation takes place in two stages as primer transportation and seconder transportation (Aykut, 1985). While the transportation of forest products from stump to the landing on road sides is called primer transportation, the transportation of forest products from landing to the forest depots by logging trucks is defined as seconder transportation. The seconder transportation accounts for about 40% of the total cost of producing forest products (Acar, 1998). Main factors affecting the cost of seconder transportation include hourly cost of truck, truck speed and load capacity, road slope, road length, road type, and road condition.

Computer aided models have been developed for planning the transportation of forest products, due to inadequacy of traditional methods which mainly depend on the planner’s experience (Akay and Erdas, 2007). Advances in computer technology and modern mathematical algorithms have made significant contributions to the development of appropriate alternative methods for solving transportation problems that require the selection of alternative with minimum cost (Sessions et al., 2001). These methods, known as network models, are used to solve problems such as finding the minimum cost distance, finding the maximum value flow, and making the most appropriate task allocations.

Sessions (1985) developed NETWORK software using an algorithm that starts with the input node points and takes the variable costs, the fixed costs and the flow rate into account. NETWORK software calculates the minimum cost or maximum net profit in objective function. Besides, NETWORK software allows users to evaluate multiple time periods and forest products in solution of large transportation problems (Akay and Erdaş, 2007). The NETWORK II program is an

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**Corresponding author: Tel: +1-225-7714500 E-mail: hande_kilic_00@subr.edu

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advanced version of this software developed for educational and commercial purposes (Sessions, 1985).

NETWORK 2000 software, a modern version of NETWORK II software, was developed by Chung and Sessions (2000) to be compatible with Microsoft Windows operating system. With NETWORK 2000, the practicality of the user interface has been improved and the problem size has been increased. Moreover, in NETWORK 2000 software, the solution capacity is also improved by using "heuristic" solution techniques. In this study, the Network 2000 program was used to plan the transportation of forest products and the solution capacity of the method was examined with a sample application. The route with the lowest net transportation cost and highest net profit was determined considering various forest products and alternative forest depots.

2. Material and Methods

2.1. Study Area

The study area is Paşalar and Sarnıç FECs of Mustafakemalpaşa FED in the border of Bursa Forest Regional Directorate. The amount of forest products (i.e. logs, industrial wood, mine pole, paper wood) and landing locations information were obtained from the Mustafakemalpasa FED. The image of the study area is given in Figure 1. The spatial distribution of forest resources, which are located within the boundaries of Mustafakemalpaşa FED, is shown in Table 1. Tree species in the study area are Beech, Oak, Fir, Brutian pine, Stone Pine, and Maritime pine.

Table1. The forest resources in the FECs (ha)

FECs	High Forest	Degraded Forest	Total Forest
Paşalar	3423.50	1596.30	10020.30
Sarnıç	4094.60	303.60	4903.20
TOTAL	80693.80	32207.90	112901.70

For the digitization of road networks, forest depots, and landing location in the study area; 1: 25000 scale topographic maps and forest management maps were used as the bases. Table 2 listed the amount of forest products that were transported to the landing area in the Paşalar FEC. Unit sales prices for these products in two forest depots (Karapınar and Sarnıç Depots) were different from each other (Table 3).

Table 2. Amount of forest products (m^3)

Logs	Industrial Wood	Mine Pole	Paper Wood
139	83	35	112

Table 3. Average sales prices of forest products (TL/m^3)

Depots	Logs	Industrial wood	Mine	Paper
Karapınar (Paşalar FEC)	198	146	166	130
Sarnıç (Sarnıç FEC)	210	155	150	117

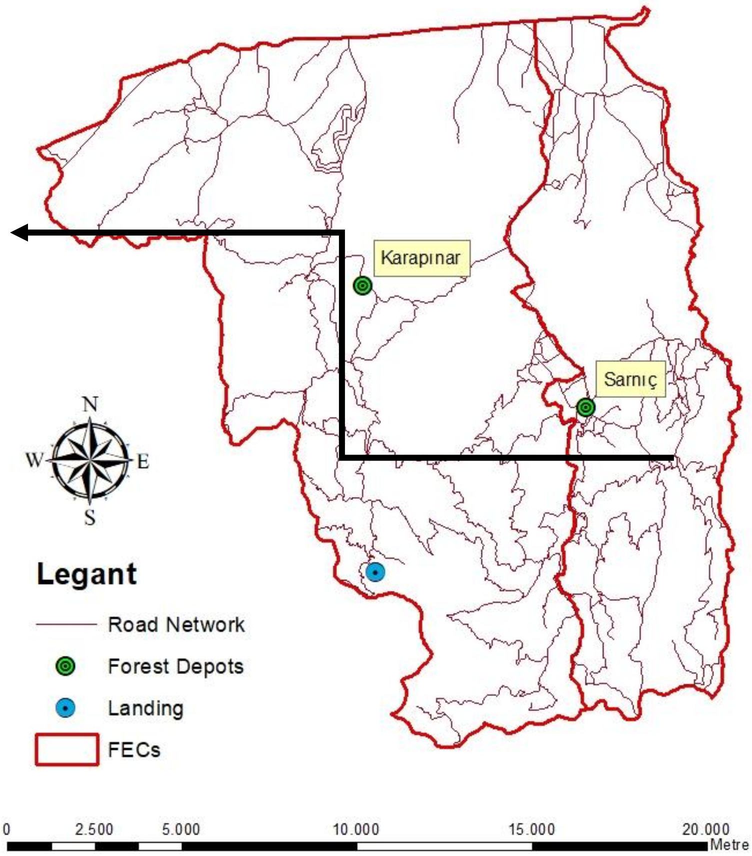

Figure 1. The study area

2.2. Network Analysis

In the network analysis approach, the transport model developed by Sullivan (1974) and the "Prorate" algorithm developed by Schnelle (1980) were used together to investigate alternative transportation routes in Network 2000 program, which was developed by using the shortest path algorithm. The algorithm determines the routes between each starting point (landing) and the destination point (forest depots). In this study, firstly the route with the minimum transportation cost was searched and then the route with the maximum net profit was determined considering the sale prices of forest products.

The most important factor in the effective use of the network model is the correct implementation of the road network. In the network analysis method, the system is formed by links (arcs) and node points intersected by links (Akay and Şakar, 2009). In this method, the shortest path was investigated by finding the route where the sum of link (road segment) values was the lowest (Akay et al., 2006). The cost of transportation for each link was the sum of the cost of truck move-out loaded and move-in unloaded. These links are shown as two separate links on the network if the loaded truck is moving in both directions on the link. Forest products which are entering the network system from landing areas can be directed to more than one forest depots. The depots in the system are connected to new node that will function as "Final Destination" (Figure 2).

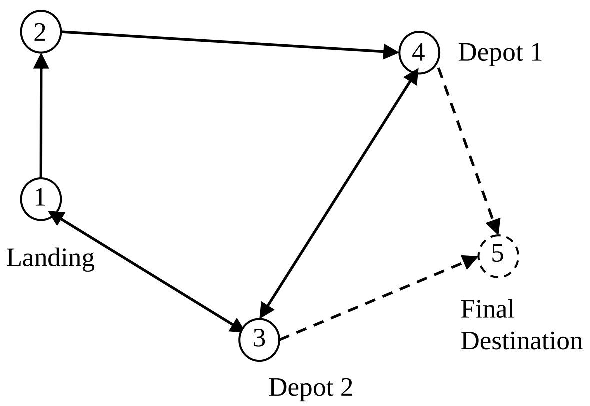

Figure 2. Network model with two separate forest depots and one final destination node (Akay and Erdas, 2007)

In this study, road network data was developed in the ArcGIS 10.2 software based on 1: 25000 scale topographical maps. During the digitization, the road type (asphalt, gravel, forest road) and average travel speed (km/hr) information for each road section were entered in the attribution table. Then, the unit transportation cost (TL/m^3) was calculated for each road section based on hourly unit cost of the logging truck (TL/hour), the load capacity of the truck (m^3), and the truck run time (hours) (Akay and Erdaş, 2007):

$$TC = HC/(L_c/T_w) \quad (1)$$

UTC : unit transportation cost (TL/m^3)
HC : hourly unit cost of the truck (TL/hour)
L_c : load capacity of the truck (m^3)
T_w : truck run time (hours)

The hourly unit cost of logging truck (46.86 TL/hour) was obtained from FED. The load capacity of the truck was determined based on the average load capacity (15 metric tons) of logging trucks used in the region. The truck run time was calculated as follows (Akay and Erdas, 2007):

$$T_w = 2L/V(1+T_d) \quad (2)$$

L: round-trip length of the link (km)
V: average truck travel speed (km/h)
T_d : delay time (asphalt: 5%, gravel: 10%, forest roads: 15%)

The average speeds for each road type were calculated by taking the average of the loaded truck speed and the unloaded truck speed. The average speed values for the forest road, gravel road, and asphalt road were 20, 30 and 60 km/h, respectively. Then, the network database was completed by entering the link information into "Link Editor" table (Figure 3) in the Network 2000 software. Then, the information of the forest product delivered to the depots were entered into "Sale Editor" table (Figure 4). In the final phase, the transportation planning has been generated by using "heuristic" techniques. Since the program is produced for solving minimization problems, positive values were given to costs while negative values were given to sales prices.

Line	From node label	To node label	Variable cost ($/unit/link)	Fixed cost ($/link)	Index
1	413	422	0.30	0.00	0.00
2	422	413	0.30	0.00	0.00
3	116	118	0.42	0.00	0.00
4	118	116	0.42	0.00	0.00
5	153	171	0.48	0.00	0.00
6	171	153	0.48	0.00	0.00
7	173	180	0.16	0.00	0.00
8	180	173	0.16	0.00	0.00
9	155	143	0.68	0.00	0.00
10	143	155	0.68	0.00	0.00
11	168	176	0.91	0.00	0.00

Figure 3. Link Editor in Network 2000

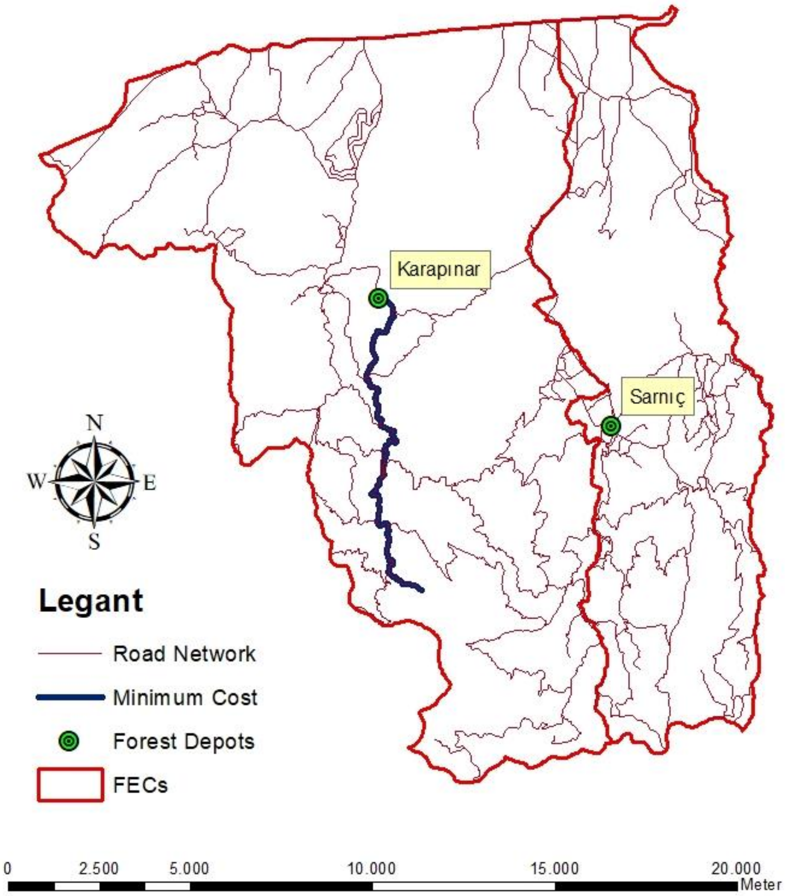

Figure 6. Route that minimizes the transportation cost for Scenario I

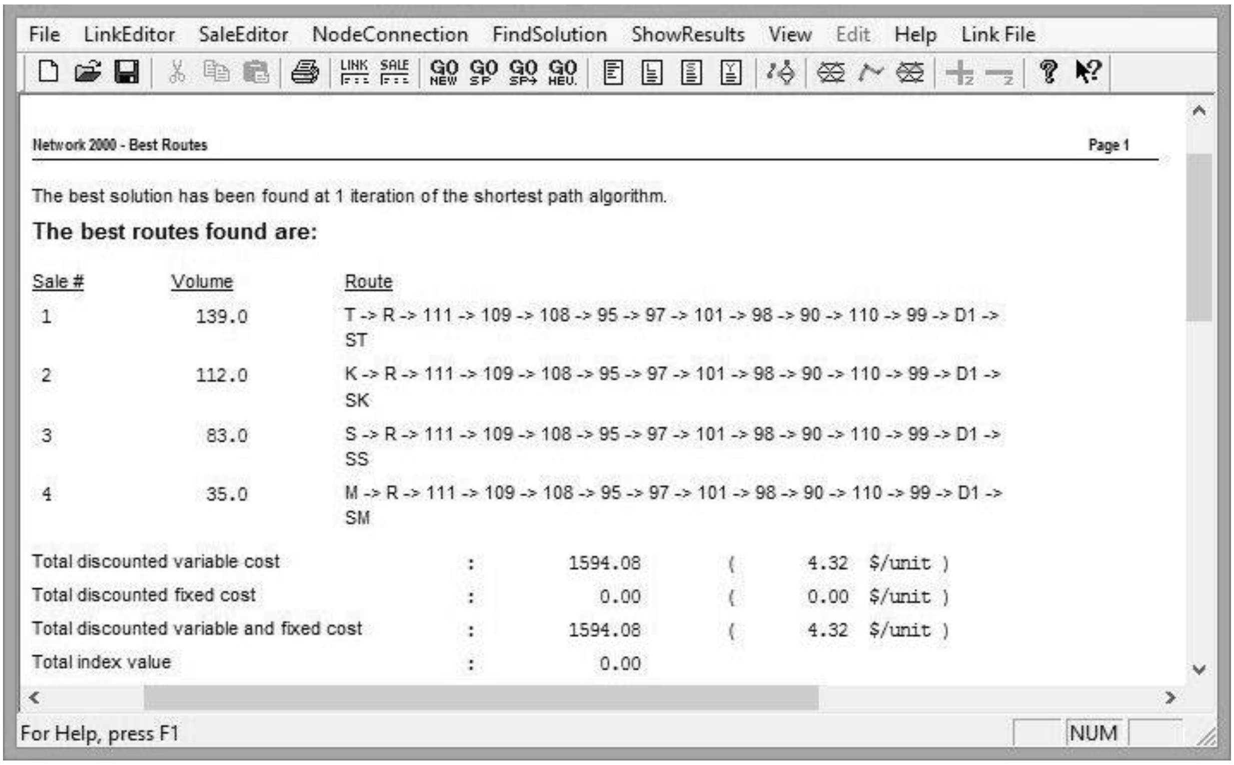

Figure 7. Network 2000 solution for Scenario I

As the second alternative in the second scenario, the forest depot at the Sarnıç was excluded from the network and forest products were only allowed to be transported to the Karapınar Depot. In this alternative, forest products were hauled by using the same route proposed in the first scenario and total net profit was found to be 58415.92 TL (Figure 10). Thus, net profit decreased by 2050.92 TL when Sarnıç Depot was excluded.

According to the results, the factors affecting the transportation unit cost in the road network were the truck run time, hourly unit cost, and load capacity. The vehicle travel speed, which affects the runtime, increases with the improvement of road status and the running time is reduced accordingly. Hourly unit cost changes depending on fuel expenses, operator costs, tire expenses, and maintenance costs (Akay and Erdas, 2007).

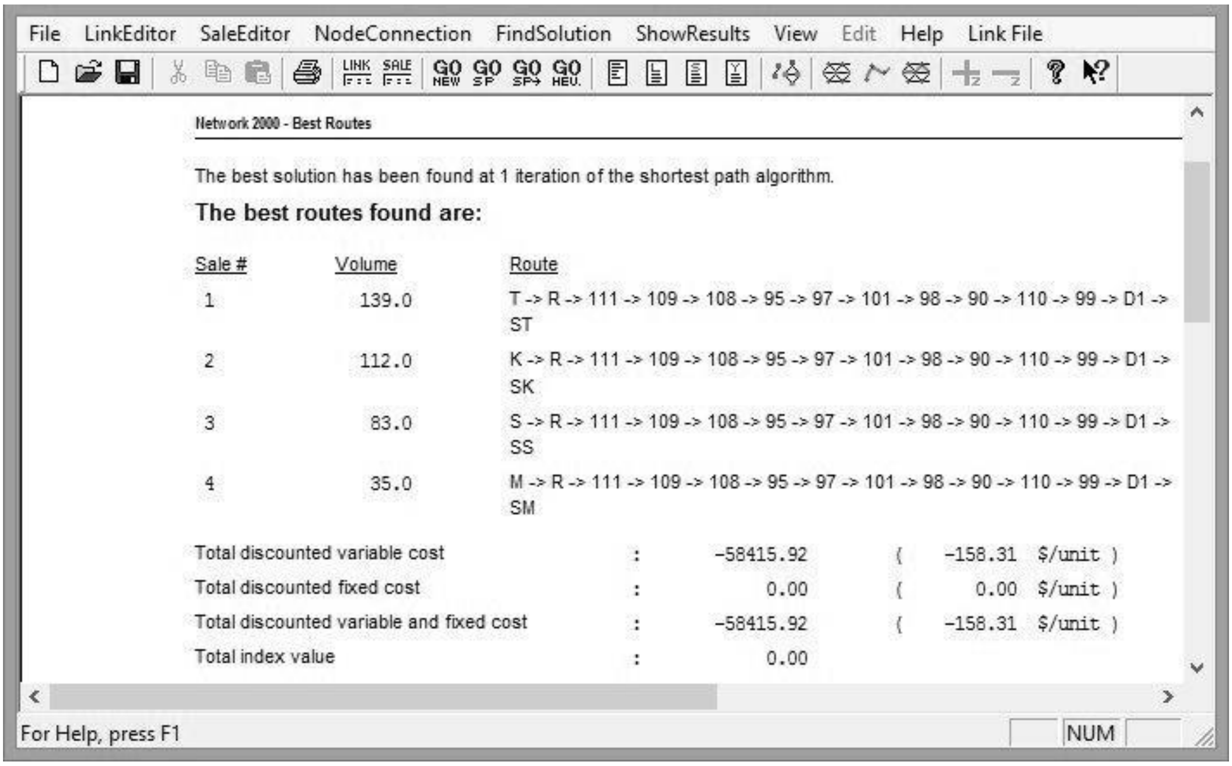

Figure 10. Network 2000 solution for Karapınar Depot in Scenario II

4. Conclusions

For the optimum planning of seconder transportation, which constitutes an important part of the total cost in the production of forest products, it is necessary to evaluate large number of alternative routes and determine the most suitable alternative. In this study, it was demonstrated that Network 2000 program can be used effectively in solving such complex transportation planning problems. This program can also assist managers to search for the effects of main factors (i.e. hourly equipment, vehicle speed, load capacity, road gradient and length, road type, and road condition) on total cost of hauling forest products to the forest depots.

For a follow up study, the locations of the existing forest depots can be evaluated and more appropriate locations for new depots can be searched by Network 2000 program. The capabilities of the program should be tested in the areas with higher road density and higher roads standards. It can be suggested that planning new roads and improving the standards of existing roads should make a significant contribution to reduce the transportation costs.

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