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A Simulated Annealing Approach to Problems of the Transportation of Wood Raw Material

Erhan Çalışkan[1], H.Hulusi Acar[2]

[1]Department of Forest Engineering, Faculty of Forestry, Karadeniz Technical University, 61080 Trabzon-Turkey
[2]Department of Forest Engineering, Faculty of Forestry, Karadeniz Technical University, 61080 Trabzon-Turkey
Corresponding author. Tel:+90 466 215 10 40; Fax:+90 466 2151034.

E-mail: erhan_caliskan@yahoo.com

Abstract: The planning process for producing wood raw materials includes forestry work such as transporation. This process is highly complex, both in implementation and design. In these studies, the transporting of wood raw material on the forest road network constitutes a significant portion of total production costs. Therefore, development of the most appropriate transportion plan is of great importance, not only technically, but also financially. In this study on the forest road network, a model of transporting wood raw material was developed. The algorithm of Simulated Annealing (SA) among the meta-heuristic techniques has been used for the analysis of the model. In order to introduce the model more explicitly, an experimental design and analysis has been applied in this study. During the process of experimental design, the multivariate analysis of variance was used in order to determine whether the applied factors are effective on the performance of the SA algorithm. Moreover, whether there is any difference between the levels for these factors was assessed by the Duncan multiple range test. It was concluded that using the transporting model in the research field can provide 14.45% savings in annual transportation costs. 'Transport planning studies' have provided significant savings in the workforce, time and cost with the use of SA and statistical methods.

Keywords*:* Forest roads, Transport of Wood Raw Material, Simulated Annealing, Optimization, Harvesting Planning.

1. Introduction

Forest roads are one of the most important infrastructure facilities, which not only enable the transportation of wood raw material from forests to sale stores or to consumption centers, but also find solutions to the problems regarding cultivating, conserving, and managing the forest process without any difficulty [1].

In Turkey, the process of wood transportation on forest roads, and partly on highways, is carried out by trucks or tractor- trailers, which is mainly the same for most countries' forests. The local people's vehicles belong to members of the cooperatives.

Transportation works are held in accordance with agreements reached between the forest enterprises and the cooperative managers. In Turkey, the most preferred vehicle type in the transportation of wood from ramps or break depots to the main depot is the truck. These are used in transporting wood raw materials such as very short logs, pulpwood, industrial wood and the like. Development in technology and the increasing need for wood necessitated the need for the development of facilities, transportation, and techniques used for carrying wood to the market areas [2].

Wood costs in Turkey are above the world average. To illustrate, harvesting costs and their transportation from roadsides to the depots is highly expensive [3, 4]. In Turkey, the total forest area is 21.2 (27%) million hectare. In these areas, an annual average production of 5 million m^3 fuel wood, and 9 million m^3 industrial wood is carried out by the government. Moreover, in the private sector, approximately 3.5 million m^3 of production takes place. According to this, the amount of total production is about 17.5 million m^3. In 2006, the amount spent for carrying wood raw material on the forest road was 80 378 000 YTL (1YTL=1.6 USD). In order to reduce this cost, it has become inevitable that optimization techniques should be used in transporting wood raw material. Unfortunately in Turkey, there is not an accepted specific method to apply this.

Pulkki [5] used GIS and heuristic programming together in order to plan the operations for carrying from the stand to the depot.

In a network planning approach Shen et al. [6] found a solution to the problem in their studies by establishing an algorithm which could minimize the transporting costs including transportation from the forest to depots, and lastly to the factories.

Schuster and others [7] stated in the study on computer based analytical tools used in forestry planning that Network, Heuristic, Simulation, Monte Carlo Sampling, Artifical Nevre, Expert Systems, Dynamic Programming, etc. Modelling techniques were used in the production of forestry (Felling, Transportation) and that various decision support tools called SNAP-II, GISTRAN, NETWORK, PLANS, TRANSMAN, TMS, RMS to be used in production planning were designed.

In the past year, the mixed integer mathematical programming and heuristic algorithms such as: TIMBRI [8], NETWORK [9], TRANSHIP [10], MINCOST [11], NETCOST and NETWORK 2000 [12, 13, 31, 32] have been used to find the appropriate solution for certain fixed and variable cost problems.

In a study applied to mountainous terrain, in order to minimize truck transport costs in mountainous areas, a "Transport Model" was used and it was explained that in the transport activities organized according to this model approximately 9.600 YTL of savings could be made[14] .

In their study, Palmgren *et al.* [15] developed a model to solve scheduling problems such as collection and transport in log transportation by truck. For this purpose, an approach was developed on the basis of the main route and fees. In the proposed mathematical model for each appropriate route only one truck was adopted.

Aruga *et al.* [16] described commonly used modern heuristic techniques (Simulated Annealing, Genetic Algorithm, Tabu Search, and Shortest Path Algorithm).Simulated Annealing was used to guide the search for the best vertical alignment that minimizes the total costs of construction, transportation, and maintenance costs for a single forest road.

Broman *et al.* [17] examined the transporting process of 70 million m3 wood material affected after the hurricane which occurred in Sweden 2005. In the aftermath of this disaster-level event, they found solutions to the issues such as which depots would be used, how to move with (trucks, trains, ships), where to store with an operational research which was an important decision support tool in the transport chain planning.

In their study Çalışkan and Acar [18], introducing Expert Systems from Artificial Intelligence techniques, Fuzzy Logic, Neural Networks, Genetic Algorithms and the Simulated Annealing method made an assessment on the use of these techniques in the production and transportation of wood raw material.

One of the significant costs of Forest management is transportation costs. Optimization of transportation costs is highly important in terms of forest enterprises which carry the wood raw material to the sale stores by the vehicles of cooperatives. The most important thing about the transport operation is the specification of minimum cost routes that will be followed to carry wood raw material from ramps or break ramps to the sales stores. Cooperatives can make savings on the costs after providing solutions to these problems [1].

The purpose of this study is to find a solution method and form a model which will allow the investigation of the routes in order to minimize transportation costs by considering wood raw material of various standards , ramps and depots.

2. Material and Methods

2.1. Material

As research areas, The Anbardağ Forest District and Giresun Forest Enterprise in the Eastern Black Sea Region, which reflects the features of mountainous terrain and where transport problems are seen in great numbers, were chosen. In this region, which is a concentrated area of transportation, the measurement and observation on the process of the transportation of spruce trees was made.

While the issues such as the partitions where wood raw material production would be carried out, ramps, transporting costs method and depots were within the scope of the work, other issues such as the process of subtraction and division before the remote transport were not addressed.

The total road length in the field of research is 226+334 km. Village path length is 89+890 km. Also, the total length of forest roads in the research area is 136+454 km. In the research area, four different wood raw materials were moved. These are: Log, Industrial wood, Mining pole and Pulpwood [19].

In the cross-country studies, for the collection of spatial data the Garmin brand GPS receiver, for distance measurement a 20-foot tape measure, and in the inclination measurement as a contributory material, a klizimeter were used.

For the solution of wood raw material transport network design and the simulated annealing algorithm, the software "Network 2008" was used. The created simulated annealing algorithm has been encoded with Visual C++2006 language.

The statistical analysis for the work was carried out by using the software "SPSS 15.0".

2.2. Assessment Method

One of the remotest transport operations, the transporting of wood raw materials by trucks on forest roads has been discussed. Here, the model was created taking into account the criteria including the ramps, forest depot, wood raw material of varying standards, time periods, road standards, alternative routes, and the most cost-effectiveness.

In the transportation model, variable costs were incurred (Miyata et al. and FAO) [20-21]. Variable costs were also incurred during the wood raw material production activity and which were consumed. At the same time, they also include the reflected fixed costs at the beginning of the operation period. For the transport costs, the following correlation was used:

Operation Cost:Variable Cost + (Fixed Cost/Size of moved product volume) (1)

Road length and average slope of the road have been determined by land movement. The average speed for each link has been calculated by taking the average speed of an empty truck and the estimated average speed of a loaded truck. Not only in the specified route, direction and speed but also in finding the time of transporting by truck, the method expressed by FAO [21], and Akay [22] has been used.

The rate of lost time for crude paths, stabilized roads and unpaved roads has been taken in the order of 15%, 10% and 5 %. After the total work time was calculated, the unit cost of transport was calculated by the following correlation:

$$BNM_i = \frac{KBM}{\left(\frac{YK}{K_i ÇZ_i}\right) * 60} \qquad (2)$$

BNM_i : For the link i, the unit transportation cost (YTL/m^3)

KBM: Hourly unit cost of the truck (YTL/hour)

YK : Load capacity of the truck (m^3)

$KÇZ_i$: Truck transportation time

60 : To convert the hourly cost of unit to minutes.

Figuring out the fixed and variable costs for the transport operation, the unit costs of transporting per m^3 product from alternative routes to the alternative depots was calculated separately according to every ramp and road standard.

In the developed model, statistical evaluation was applied to find the most appropriate parameter set for the SA algorithm. The Multiple analysis of variance was used to determine whether the implemented factors are effective in the performance of the SA algorithm (α: 0,05 significant level). Whether there exists a significant difference in the considered levels for these factors was evaluated by the Duncan multiple range test.

2.3. Simulated Annealing Method and Implementation of the Model

The Simulated Annealing (SA) method is a mathematical solution technique which uses both comprehensive search techniques in the optimal solution of complex problems, and also research techniques concentrating on specific areas based on the sequential solution [23].

It is a probabilistic research technique providing good solutions for SA optimization problems. It was proposed by Kirkpatrick and his assosciates in [24]. It is based on the principle of heating solids and cooling them slowly until crystallization. The temperature value is used to determine the acceptance probability of a worse solution than the best solution which has been obtained. Simulated annealing begins with a high temperature value. In each calculation step, many solutions are found among the neighbors of the current solution. New solutions are accepted or rejected according to a determined criterion. After each calculation, the temperature is reduced according to a determined function. The algorithm is terminated when the desired iteration is reached, when the temperature reaches the minimum value, or when the desired solution is obtained. According to the simulation annealing method of the combinatorial problems, there are four basic components in the mathematical formulation and solution [25-26]. These are;

- Defining the system
- Determination of a general objective function
- Creation of a solution change strategy
- Determination of control parameters that will direct the solution

In the implementation of the model, 4 different wood raw materials produced in 2007 (log, industrial wood, mine pole, pulpwood) existing in 10 sections of the Giresun Forest District Office in the Chieftaincy Anbardağ Forest District, and the most appropriate transport routes were investigated in the process of their transportation from 10 ramps in the forest of the Chieftaincy Anbardağ Forest District to the Kovanlı store or to the Bicik store located in the neighboring business chieftaincy. In the scenario, the cost transport minimizing was researched (MODEL1). Moreover, the scenario (in itself) was tested for two separate alternative forest depots. While in the first alternative, wood raw material is allowed to reach both forest depots (MODEL1-1), in the second alternative, it reaches only the forest depot belonging to the business chieftaincy where production is carried out (MODEL1-2). Thus, savings that can be made in transporting wood raw material are calculated based on the fact that the forest management is allowed to use different forest depots.

2.4. Application of Simulated Annealing to the Problem of Transporting Wood Raw Material

2.4.1.Definition of the System

Ramps, road nodes and depots from i=R1,R2……to N, from i=1,2,….to N and from i=D1,D2………to N were located into the determined coordinates (x, y). System configuration is the permutation of numbers from 1 to N.

2.4.2.Change Strategy

Here, three different sets of actions are identified.

1. Generate a feasible route by random selection of nodes among the candidates.
2. Select only one sale and apply a different route at each iteration.
3. The higher the route cost, the greater the chance to be selected for improvement.

2.4.3.Function of the Objective

It is the determination of the route which minimizes the total variable and fixed costs among the alternative routes, and is calculated as follows:

$$\text{Zmin} = \sum_{p=1}^{P} \sum_{r=1}^{R} \sum_{k=1}^{K} \sum_{g=1}^{G} DMprkg * Hprkg + \sum_{p=1}^{P} \sum_{t=1}^{T} \sum_{g=1}^{G} SMptg * Xptg + penalty\ value \quad (3)$$

In this model the defined sets are;

P: Planning number

R: Number of ramps in the planning year

K: Number of trucks in the planning year

G: Number of routes that can be used in transporting wood raw material from ramps to depots.

T: Number of new road types (quality) that will be built in the planning year.

DM_{prkg} = Coefficient of the transportation cost which arises using g route and k truck type and the variable cost coefficient (YTL/m^3) in p period from r ramp.

H_{prkg} = Decision variable(m^3) which defines the quantity that is able to carry in *prkg* conditions. It is the amount of transported wood raw material. It is also the wood raw material amount using k truck type and g route from ramp r in p period.

SM_{ptg} = Fixed cost (YTL/m). Road construction cost of growth which is t type in p period.

X_{ptg} = Binary (0,1) decision variables, showing the construction of g path in t type and p period.

In this function, X_i, is the binary variable whose value takes 1 if i route is used, and if not it takes 0.

Decision variable that will be put in the model;

In any period, volume (m^3) of k wood raw material that is carried from any ramp to any depot (X_{pbdk}) (= volume of k wood raw material that is carried from b ramp to d depot in p period).

The model was subjected to volume restriction (lower and upper limit). The upper and lower limits of the wood volume constraints will be analyzed. If the total volume of wood is lower than the lower limit and exceeds the upper limit for the route, a penalty value occurs. The upper limit is determined as 1000m^3 and the low limit is determined as 10 m^3.

Analyzing every route according to whether it exceeds the limit or not, the total penalty coefficient value will be 1000 if the total volume value of wood raw material is less than the lower limit or bigger than the upper limit.

Penalty value: demand amount- transport amount.

2.4.4.Simulated Annealing Plan

In the adaptation process of the problem to the simulated annealing algorithm, firstly, the annealing schedule should be determined.

- ✓ Initial Temperature, (T);
- ✓ Number of Iterations,(m);
- ✓ Cooling Rate, (r);
- ✓ Minimum Temperature, (T_1) ;
- ✓ Determination of stop condition, ($T<T_1$) ;

Initial temperature values used in the solutions for the problems, which were developed through selecting from the literature, have been used in the developed SA algorithm. The initial acceptance probability (Pb) was as 0.95, and the final acceptance probability was taken as $1*10^{-15}$. For the solutions of all the models, 3 different initial temperatures were used. The cooling rate varies according to the number of iterations, and the values are between 0.65 and 0.95. For each model, attempts have been made at a different number of iterations.

In the process of optimization, the model randomly gets an appropriate route for each depot from the points whose coordinates had already been determined (Figure 1).

3. Result and Discussion

3.1.Results in the Searched Road Network System

Some features of the road links in the network system (length, road type, average slope, speed, total run time and unit transportation costs) are shown in Table 1.

Stand types of the partitions in the harvesting field, and the amount of produced wood raw material area are shown in Table 2 . Products (after secondary transport) which are produced in compartmenst 63, 37, 89, 69, 41, 73, and 46 are stacked in the R2, R3, R4, R5, R6, R8 and R10 numbered ramps. The wood produced in the 88-114, 65-66 and 52-53 numbered compartments reached the R1, R7 and R9 numbered ramps.

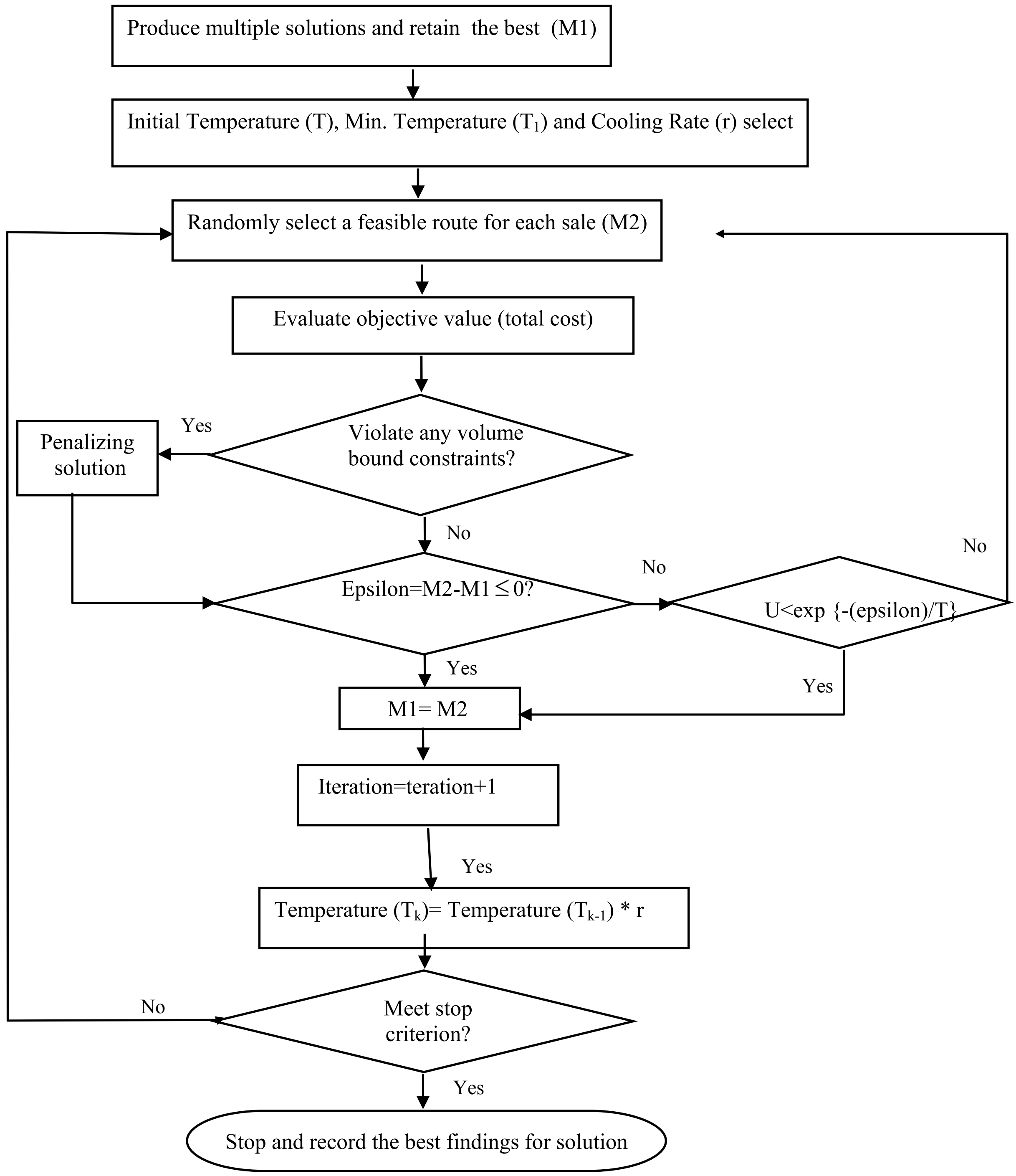


Figure 1. Flow Diagram of the Simulated Annealing algorithm developed for the wood raw material transportation difficulties

Epsilon (M2-M1): The difference between the values of the new found neighbouring solution, and the objective function of the previous solution.

Table 1. Routes' transportation model properties in the transportation model

Routes	Road Length (Km)	Road Type	Average Road Gradient (%)	Average Vehicle Speed (km/hour)	Truck Transporation Time (minute)	Delay Time (minute)	Total Time (minute)	Unit Cost (YTL/m^3)
R1-R2	1.486	RawRoad	4	15	11.9	1.78	13.67	0.34
R2-1	0.298	RawRoad	7	15	2.38	0.36	2.74	0.07
R3-1	2.252	Stabilize	6	25	10.81	1.08	11.89	0.30
1-R4	1.083	Stabilize	6	25	5.20	0.52	5.72	0.14

R4-2	0.706	RawRoad	3	15	5.65	0.85	6.50	0.16
2-3	0.447	Stabilize	5	25	2.15	0.21	2.36	0.06
3-4	0.955	RawRoad	8	15	7.64	1.15	8.79	0.22
4-R5	2.263	Stabilize	7	25	10.86	1.09	11.95	0.30
R5-5	0.464	RawRoad	8	15	3.71	0.56	4.27	0.11
5-6	0.899	Stabilize	6	25	4.32	0.43	4.75	0.12
R6-R7	2.007	RawRoad	5	15	16.06	2.41	18.46	0.46
R7-7	2.506	RawRoad	3	15	20.05	3.01	23.06	0.57
7-8	0.412	Stabilize	5	25	1.98	0.20	2.18	0.05
8-6	0.566	RawRoad	7	15	4.53	0.68	5.21	0.13
6-9	1.089	RawRoad	5	15	8.71	1.31	10.02	0.25
9-R10	1.819	Stabilize	6	25	8.73	0.87	9.60	0.24
R8-10	0.519	RawRoad	2	15	4.15	0.62	4.77	0.24
10-R9	0.371	RawRoad	5	15	2.97	0.45	3.41	0.12
R9-11	1.556	RawRoad	5	15	12.45	1.87	14.32	0.08
9-11	1.33	Stabilize	6	25	6.38	0.64	7.02	0.36
11-DB	7.817	Stabilize	7	25	37.52	3.75	41.27	0.17
R10-12	2.194	Stabilize	6	25	10.53	1.05	11.58	0.29
12-DK	10.866	Asphalt	5	35	37.25	1.86	39.12	0.97
8-13	2,.67	RawRoad	5	15	18.94	2.84	21.78	0.54

Table 2. Amounts (m^3) of wood raw material produced in each compartment and stand types

Ramp Number	Compartment Number	Stand Type	Log (m^3)	Industrial Wood (m^3)	Mine Pole (m^3)	Pulpwood (m^3)
R1	88-114	Lc_2-$LKnc_2$	473.700	34.400	58.900	14.500
R2	63	$LKnd_1c_2$	540.900	114.700	10.200	13.100
R3	37	$LKnd_1c_2$	350.300	202.000	37.800	13.700
R4	89	Lc_2	84.300	201.400	31.000	11.800
R5	69	Lb_1	943.000	236.700	238.600	47.800
R6	41	$LKnd_1c_2$	83.400	12.600	25.900	10.300
R7	65-66	Lc_2-$LKnc_2$	222.800	70.000	31.600	10.800
R8	73	Lc_2	308.500	40.600	17.900	11.800
R9	52-53	Lc_2	547.000	25.900	89.300	10.200
R10	46	$LKnd_1$	122.500	31.100	30.700	15.800
		Total	3676.400	969.400	571.900	159.800

3.2. Results of Simulated Annealing Application Findings and Discussion

The SA algorithm, which was developed in this study, involves 4 different parameters; T, the initial temperature algorithm; T1, the minimum temperature that determines when the algorithm will end; step numbers that should be accepted at each temperature (iteration, m) and the cooling rate determining

how much the temperature will decrease after the number of steps have been completed. 3^k! (k=4) Attempts were made to get 3 different level performances of factors taken into account organizing factorial experimental design. Accordingly, the factors included in the experimental design and their levels are given at Table 3.

Table 3. Factors and their levels included in the experiment design

Factors	Levels		
	Low	Medium	High
1. Initial Temperature (T)	10000	20000	30000
2. Minimum Temperature (T_1)	10	20	30
3. Cooling Rate (r)	0.65	0.85	0.95
4. Number of Iterations (m)	1000	2000	3000

In the experimental design which was organized for the SA algorithm as a result of pilot experiments, the 3 different levels selected for the initial temperature were 10000, 20000 and 30000; However, 10, 20 and 30 values were considered for the minimum temperature. The R value that will determine at which rate the temperature will be cooled was taken at the levels 0.65, 0.85 and 0.95, and also was chosen as total 81 parameters combinations, including 1000, 2000 step numbers and 3000 iteration numbers that will be accepted at every temperature value during the algorithm. The various annealing plans were suggested [27-28]. An earlier proposed plan was the one put forward by Kirkpatrick and others [24], based on the analogy with physical annealing.

According to this simulated annealing plan, the initial value of the T temperature parameter was chosen as high as possible for all the actions to be accepted with an aim of imitating the organization of all the particles randomly when the element reaches the liquid phase. After a sufficient number of solutions were examined in the pilot experiments for Model 1- 1 and Model 1 -2 whose optimum solutions are unknown, it was revealed that the developed algorithm established highly credible solutions. The study of algorithm for this model was suspended after a certain number solution points had been observed.

3.3. The Experimental Findings and Discussion for Model 1-1 According to SA Algorithm

There were 5 experiments carried out by choosing random initial solutions at every level of combination which were chosen to compose for Model 1-1. According to this, the total experiment number is 405(=3^4x5). 81 of them were reported as the experiments which obtained the best results. For Model 1-1, the 81 different experiments, the solutions and the parameters are shown in Table 4. Moreover, according to the solution amount for Model 1-1, the variations of the transportation costs are shown in Figure 2.

Table 4. The experiments and results for the Model1–1 problem

T	r	m	T_1	Z_{object} (YTL)	Çs (sn)	T	r	m	T_1	Z_{object} (YTL)	Çs (sn)
10000	0,65	1000	10	11378.56	12	20000	0.85	2000	30	11314.72	45
10000	0,65	1000	20	11378.56	9	20000	0.85	3000	10	11311.19	80
10000	0,65	1000	30	11378.56	8	20000	0.85	3000	20	11311.19	75
10000	0,65	2000	10	11332.53	22	20000	0.85	3000	30	11311.19	70
10000	0,65	2000	20	11332.53	17	20000	0.95	1000	10	11311.19	85
10000	0,65	2000	30	11332.53	13	20000	0.95	1000	20	11311.19	80
10000	0,65	3000	10	11332.53	30	20000	0.95	1000	30	11311.19	75
10000	0,65	3000	20	11332.53	26	20000	0.95	2000	10	11311.19	156
10000	0,65	3000	30	11332.53	24	20000	0.95	2000	20	11311.19	151
10000	0,85	1000	10	11332.53	25	20000	0.95	2000	30	11311.19	146
10000	0,85	1000	20	11332.53	23	20000	0.95	3000	10	11309.52	233
10000	0,85	1000	30	11332.53	21	20000	0.95	3000	20	11309.52	230
10000	0,85	2000	10	11330.27	56	20000	0.95	3000	30	11309.52	228
10000	0,85	2000	20	11330.27	51	30000	0.65	1000	10	11309.52	15
10000	0,85	2000	30	11330.27	46	30000	0.65	1000	20	11309.52	12
10000	0,85	3000	10	11330.27	85	30000	0.65	1000	30	11309.52	10
10000	0,85	3000	20	11330.27	80	30000	0.65	2000	10	11309.52	25
10000	0,85	3000	30	11330.27	75	30000	0.65	2000	20	11309.52	20
10000	0,95	1000	10	11330.27	80	30000	0.65	2000	30	11309.52	15
10000	0,95	1000	20	11330.27	75	30000	0.65	3000	10	11309.52	33
10000	0,95	1000	30	11330.27	70	30000	0.65	3000	20	11309.52	30
10000	0,95	2000	10	11319.23	155	30000	0.65	3000	30	11309.52	27
10000	0,95	2000	20	11319.23	150	30000	0.85	1000	10	11309.52	30
10000	0,95	2000	30	11319.23	145	30000	0.85	1000	20	11309.52	25
10000	0,95	3000	10	11314.72	230	30000	0.85	1000	30	11309.52	20
10000	0,95	3000	20	11314.72	228	30000	0.85	2000	10	11309.52	60
10000	0,95	3000	30	11314.72	225	30000	0.85	2000	20	11309.52	55
20000	0,65	1000	10	11314.72	13	30000	0.85	2000	30	11309.52	50
20000	0,65	1000	20	11314.72	10	30000	0.85	3000	10	11309.52	85
20000	0,65	1000	30	11314.72	9	30000	0.85	3000	20	11309.52	80
20000	0,65	2000	10	11314.72	20	30000	0.85	3000	30	11309.52	75
20000	0,65	2000	20	11314.72	15	30000	0.95	1000	10	11309.52	90
20000	0,65	2000	30	11314.72	13	30000	0.95	1000	20	11309.52	85
20000	0,65	3000	10	11314.72	30	30000	0.95	1000	30	11309.52	80
20000	0,65	3000	20	11314.72	25	30000	0.95	2000	10	11309.52	185
20000	0,65	3000	30	11314.72	20	30000	0.95	2000	20	11309.52	180
20000	0,85	1000	10	11314.72	34	30000	0.95	2000	30	11309.52	175

20000	0,85	1000	20	11314.72	29	30000	0.95	3000	10	11309.52	236
20000	0,85	1000	30	11314.72	25	30000	0.95	3000	20	11309.52	233
20000	0,85	2000	10	11314.72	55	30000	0.95	3000	30	11309.52	230
20000	0,85	2000	20	11314.72	50						

The explanations related to columns in the Table are given below:
T: İnitial Temperature, r:Cooling Rate, m: Number of Iterations, T_1:Minimum Temperature, Z_{object}:Transportation Cost (YTL), Çs:Solution Watch (second)

As the initial temperature values increase from 10000 degrees to 30000 degrees, it was revealed that the total improvement values increase. The reason for this could be explained as; when the initial temperature for the problem we are dealing with remained high enough, the problem slips from the local optimum values and searches for better results.

The findings of similar results of almost all of the 81 experiments for the Model1-1 strengthen the inference of finding the optimal results for this model.

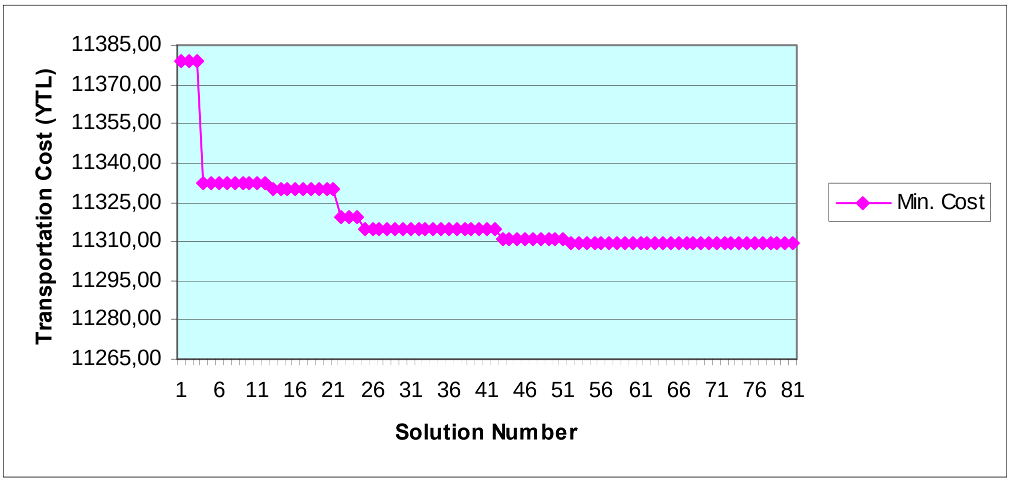


Figure 2. For Model1-1 problem, the variation of transportation costs according to the solution number

The speed of the approaching optimum solution of the SA algorithm for the best solution for Model 1-1 was found on the 53rd solution number. The algorithm reached 65.4% improving value on 53rd solution number.

3.3.1. The Analysis of Experiment Design According to SA Algorithm for Model1-1

The result obtained from the analyzed Model 1-1 is given in Table 4. However, analyzing the factors affecting the solutions obtained and identifying which factors are more effective are of importance on account of explaining the model better. For this reason experimental design and analysis have to be done. Experimental design work was carried out for the developed Model 1-1.

The main effects and maximum two coefficient effects were analyzed with multiple analysis of variance. In the outcome of the Variance Analysis, when P values (significance levels) were analyzed, we see that all the major effects which are considered except for the minimum temperature (T_1) are effective at a level of α = 0,05 relevance on Model-1 of the performance of the SA algorithm. Furthermore, all the two coefficient effects except for coefficient effects of initial temperature (T) - minimum temperature (T1), Cooling rate (r)-minimum temperature (T1), The number of the steps(m)-minimum temperature have been found relevant.

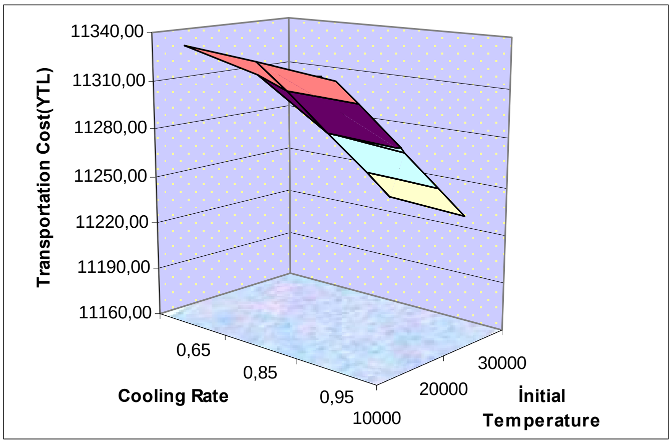
The initial temperature, cooling rate and the number of the steps are major entities of the SA algorithm. It can be seen that these have a great impact on the solution. This situation can be considered as a great advantage of the model. Because it has been seen that even with the problems of transporting a wide range of wood raw materials, we can reach a solution in a short time.

These results obtained from the multiple variance analysis stress the importance of the annealing plan in order to make the SA algorithm effective. Whether there was any considerable difference among the considered levels of the major factors which were found effective in the SA algorithm performance with multiple variance analysis was again assessed by the Duncan multiple test.

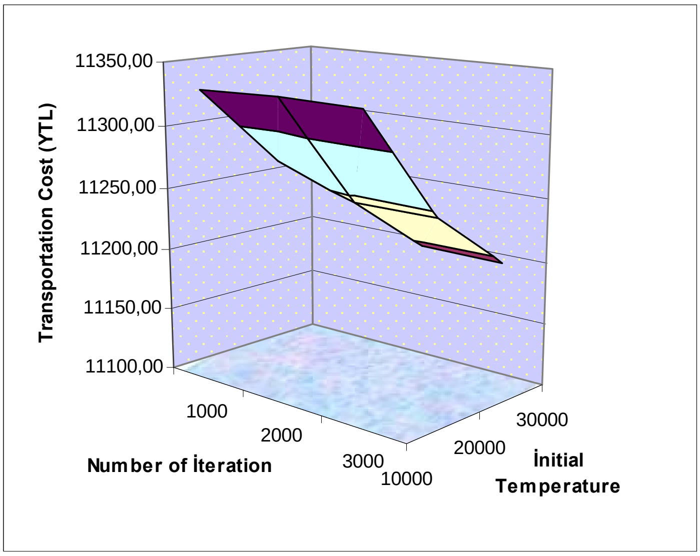
When we analyzed the results of the Duncan Multiple Spacing Test for the Model 1-1 of TB algorithm, at α = 0,05 level of suggestiveness, while low, medium and maximum levels of minimum temperature has no considerable difference; all the combinations of 3 different levels which were chosen for the parameters of initial temperature, cooling rate and iteration number caused SA algorithm to show a different performance.

The levels of 0.95 cooling rate and 30000 initial temperature (a), the levels of 3000 iteration number and that of 30000 cooling rate (b), the levels of 0.95 cooling rate and 3000 iteration number decrease the rate of transportation cost in YTL currency(Figure 3).

İteration:0

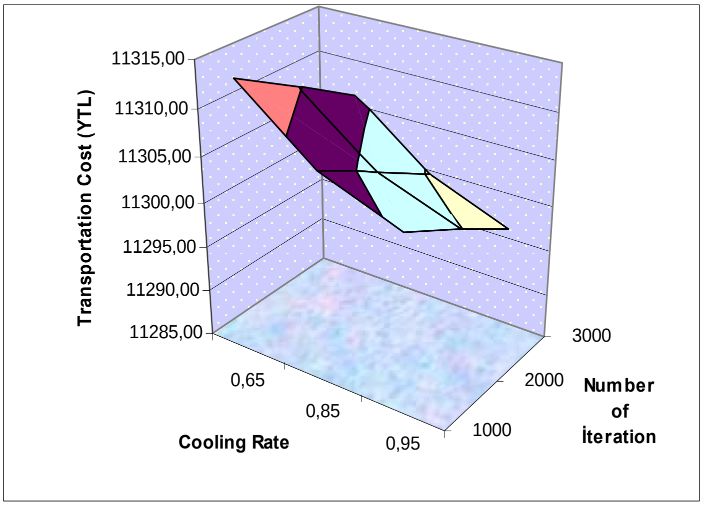


(a)



Cooling Rate:0

(b)



İnitial Temperature:0

(c)

Figure 3. The surface graph of the common effects of the Cooling rate and initial temperature(a), Number of iteration and initial temperature(b), Cooling rate and number of iteration(c) on transportation costs

The parameters of the SA Algorithm are defined below according to the Multiple Variance Analysis, and the Duncan multiple range test for Model 1-1. With the Duncan multiple range test, in choosing the values of similar parameters, the state of the algorithm functioning in less time is considered. The SA parameters for Model 1-1;

$T= 30000$, $r= 0.95$, $m= 3000$, $T_1= 20$

3.3.2.The Most Appropriate Alternative Routes and Transportation Cost for Model1-1

By using the most appropriate SA parameters of (T= 30000, r= 0.95, m= 3000, T_1= 20), the routes which lowered down the total transportation cost of obtained wood raw materials are shown in Table 5. While all the wood raw materials which were stowed on the ramp labeled R10 were transported to the Kovanlı depot, the wood raw materials which were stowed on the ramps labeled R1, R2, R3, R4, R5, R6, R7, R8 and R9 were transported to the neighboring depot, the Bicik depot (Figure 4). According to this, the total transportation cost was calculated at 11309.52 YTL.

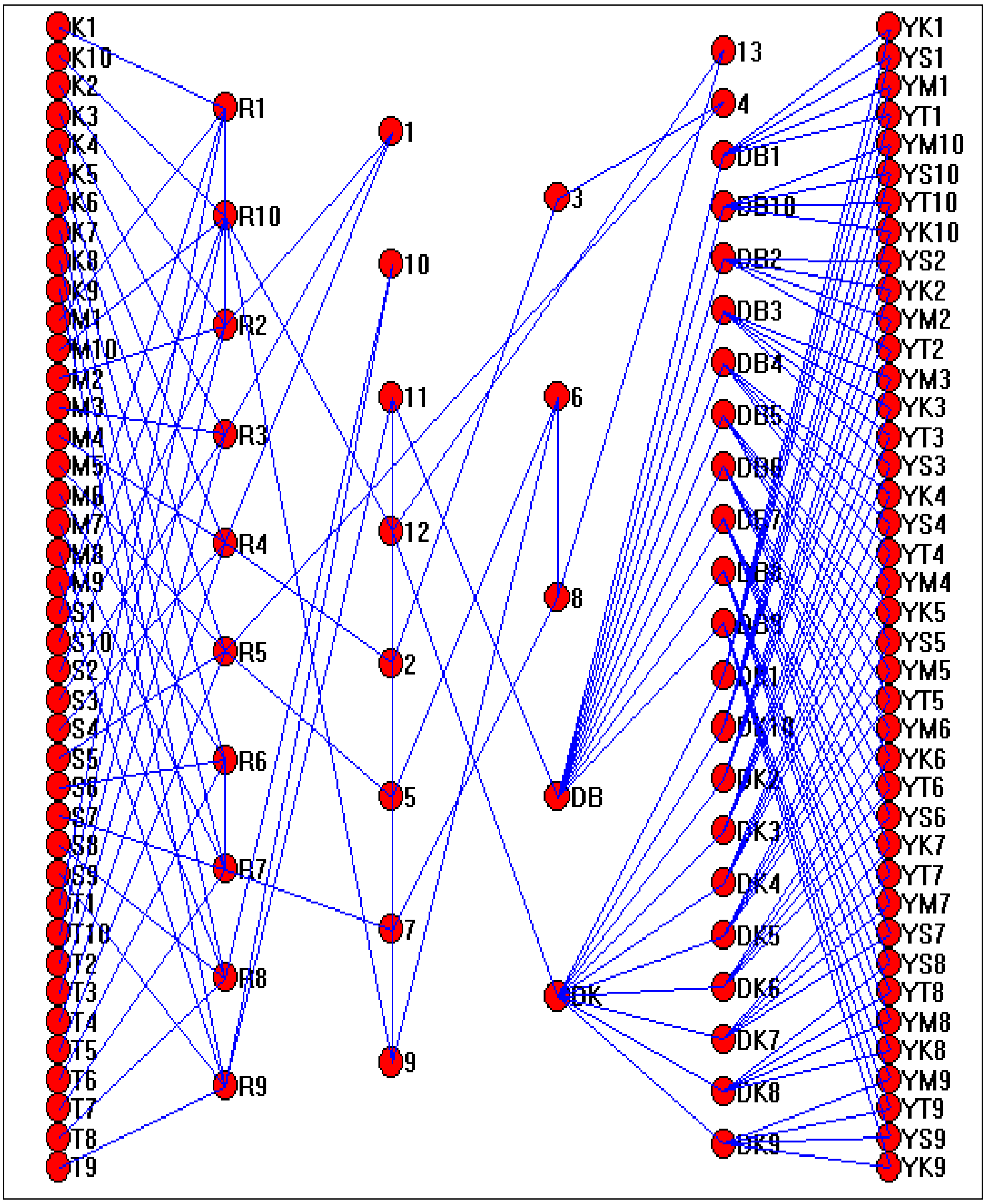


Figure 4. Transportation routes developed for Model1–1
R1, R2,..:Ramp icon, 1,2,3…:Road network nodes
T1, S1, M1, K1: Wood raw materials(Log, Industrial wood, Mine pole, Pulpwood)
DK, DB: Forest depots(Kovanlı, Bicik)
DK1, DB1: Wood raw materials from the ramps warehouse location of artificial
YT1, YM1,YS1,YK1: Icon showing the four different wood raw materials which come down the ramp

Table 5. The Routes which lower down the transportation cost for each wood raw material to the minimum level for Model 1-1

Raw material	Harvesting	The Best Routes

Volume (m^3)	Points	
4737	T1	T1->R1->R2->1->R4->2->3->4->R5->5->6->9->11->DB->DB1->YT1
540.9	T2	T2->R2->1->R4->2->3->4->R5->5->6->9->11->DB->DB2->YT2
350.3	T3	T3->R3->1->R4->2->3->4->R5->5->6->9->11->DB->DB3->YT3
84.3	T4	T4->R4->2->3->4->R5->5->6->9->11->DB->DB4->YT4
943.0	T5	T5->R5->5->6->9->11->DB->DB5->YT5
83.4	T6	T6->R6->R7->7->8->6->9->11->DB->DB6->YT6
222.8	T7	T7->R7->7->8->6->9->11->DB->DB7->YT7
308.5	T8	T8->R8->10->R9->11->DB->DB8->YT8
547.0	T9	T9->R9->11->DB->DB9->YT9
122.5	T10	T10->R10->12->DK->DK10->YT10
34.4	S1	S1->R1->R2->1->R4->2->3->4->R5->5->6->9->11->DB->DB1->YS1
114.7	S2	S2->R2->1->R4->2->3->4->R5->5->6->9->11->DB->DB2->YS2
202.0	S3	S3->R3->1->R4->2->3->4->R5->5->6->9->R10->12->DB ->DB3->YS3
201.4	S4	S4->R4->2->3->4->R5->5->6->9->11->DB->DB4->YS4
236.7	S5	S5->R5->5->6->9->11->DB->DBS->YS5
12.6	S6	S6->R6->R7->7->8->6->9-> 11->DB->DB6->YS6
70.0	S7	S7->R7->7->8->6->9->11->DB->DB7->YS7
40.6	S8	S8->R8->1 0 ->R9->11->DB->DB8->YS8
25.9	S9	S9->R9->11->DB->DB9->YS9
31.1	S10	S10->R10->12->DK->DK10->YS10
58.9	M1	M1->R1->R2->1->R4->2->3->4->R5->5->6->9->R10->12>DB>DB1>YM1
10.2	M2	M2->R1->1->R4->2->3->4->R5->5->6->9->1 1 ->DB->DB2->YM2
37.8	M3	M3->R3->1->R4->2->3->4->R5->5->6->9->11->DB->DB3->YM3
31.0	M4	M4->R4->2->3->4->R5->5->6->9->R10->DB->DB4->YM4
238.6	M5	M5->R5->5->6->9->11->DB->DB5->YM5
25.9	M6	M6->R6->R7->7->8->6->9->1 1 ->DB->DB6->YM6
31.6	M7	M7->R7->7->8->6->9->1 1 ->DB->DB7->YM7
17.9	M8	M8->R8->10->R9->1 1 ->DB->DB8->YM8
89.3	M9	M9->R9->11->DB->DB9->YM9
30.7	M10	M10>R10->9->1 1 ->DK->DK10->YM10
14.5	K1	K1->R1->R2->1->R4->2->3->4->R5->5->6->9->1 1 ->DB->DB1->YK1
13.1	K2	K2-> R2->1->R4->2->3->4->R5->5->6->9->R10->DB->DB2->YK2
13.7	K3	K3-> R3->1->R4->2->3->4->R5->5->6->9->11->DB->DB3->YK3
11.8	K4	K4-> R4-> 2->3->4->R5->5->6->9->11->DB->DB4->YK4
47.8	K5	K5->R5->5->6->9->11->DB->DB5->YK5
10.3	K6	K6-> R6->R7->7->8->6->9->11->DB->DB6->YK6
10.8	K7	K7-> R7-> 7->8->6->9->11->DB->DB7->YK7
11.8	K8	K8-> R8->10->R9->11->DB->DB8->YK8
10.2	K9	K9-> R9->11->DB->DB9->YK9
15.8	K10	K10-> R10->9->11->DK->DK10->YK10

3.4. The Experimental Findings and Discussion for Model 1-2 According to SA Algorithm

There were 81 experiments reported as the giving the best results. For Model 1-2, the 81 different experiments, the solutions and the parameters are shown in Table 6. Moreover, according to the solution amount for Model 1-2, the variations of the transportation costs are shown in Figure 5.

Table 6. The experiments and the results for the Model1–2 problem

T	r	m	T_1	Z_{object} (YTL)	Çs (sn)	T	r	m	T_1	Z_{object} (YTL)	Çs (sn)
10000	0.65	1000	10	13310.56	12	20000	0.85	2000	30	13217.19	45
10000	0.65	1000	20	13310.56	9	20000	0.85	3000	10	13217.19	80
10000	0.65	1000	30	13310.56	8	20000	0.85	3000	20	13217.19	75
10000	0.65	2000	10	13280.53	22	20000	0.85	3000	30	13217.19	70
10000	0.65	2000	20	13280.53	17	20000	0.95	1000	10	13217.19	85
10000	0.65	2000	30	13280.53	13	20000	0.95	1000	20	13217.19	80
10000	0.65	3000	10	13280.53	30	20000	0.95	1000	30	13217.19	75
10000	0.65	3000	20	13280.53	26	20000	0.95	2000	10	13206.66	156
10000	0.65	3000	30	13280.53	24	20000	0.95	2000	20	13206.66	151

10000	0.85	1000	10	13280.53	25	20000	0.95	2000	30	13206.66	146
10000	0.85	1000	20	13280.53	23	20000	0.95	3000	10	13206.66	233
10000	0.85	1000	30	13280.53	21	20000	0.95	3000	20	13206.66	230
10000	0.85	2000	10	13272.27	56	20000	0.95	3000	30	13206.66	228
10000	0.85	2000	20	13272.27	51	30000	0.65	1000	10	13206.66	15
10000	0.85	2000	30	13272.27	46	30000	0.65	1000	20	13206.66	12
10000	0.85	3000	10	13272.27	85	30000	0.65	1000	30	13206.66	10
10000	0.85	3000	20	13272.27	80	30000	0.65	2000	10	13206.66	25
10000	0.85	3000	30	13272.27	75	30000	0.65	2000	20	13206.66	20
10000	0.95	1000	10	13272.27	80	30000	0.65	2000	30	13206.66	15
10000	0.95	1000	20	13272.27	75	30000	0.65	3000	10	13206.66	33
10000	0.95	1000	30	13272.27	70	30000	0.65	3000	20	13206.66	30
10000	0.95	2000	10	13258.24	155	30000	0.65	3000	30	13206.66	27
10000	0.95	2000	20	13258.24	150	30000	0.85	1000	10	13206.66	30
10000	0.95	2000	30	13258.24	145	30000	0.85	1000	20	13206.66	25
10000	0.95	3000	10	13233.72	230	30000	0.85	1000	30	13206.66	20
10000	0.95	3000	20	13233.72	228	30000	0.85	2000	10	13206.66	60
10000	0.95	3000	30	13233.72	225	30000	0.85	2000	20	13206.66	55
20000	0.65	1000	10	13233.72	13	30000	0.85	2000	30	13206.66	50
20000	0.65	1000	20	13233.72	10	30000	0.85	3000	10	13206.66	85
20000	0.65	1000	30	13233.72	9	30000	0.85	3000	20	13206.66	80
20000	0.65	2000	10	13233.72	20	30000	0.85	3000	30	13206.66	75
20000	0.65	2000	20	13233.72	15	30000	0.95	1000	10	13206.66	90
20000	0.65	2000	30	13233.72	13	30000	0.95	1000	20	13206.66	85
20000	0.65	3000	10	13233.72	30	30000	0.95	1000	30	13206.66	80
20000	0.65	3000	20	13233.72	25	30000	0.95	2000	10	13206.66	185
20000	0.65	3000	30	13233.72	20	30000	0.95	2000	20	13206.66	180
20000	0.85	1000	10	13233.72	34	30000	0.95	2000	30	13206.66	175
20000	0.85	1000	20	13233.72	29	30000	0.95	3000	10	13206.66	236
20000	0.85	1000	30	13233.72	25	30000	0.95	3000	20	13206.66	233
20000	0.85	2000	10	13233.72	55	30000	0.95	3000	30	13206.66	230
20000	0.85	2000	20	13233.72	50						

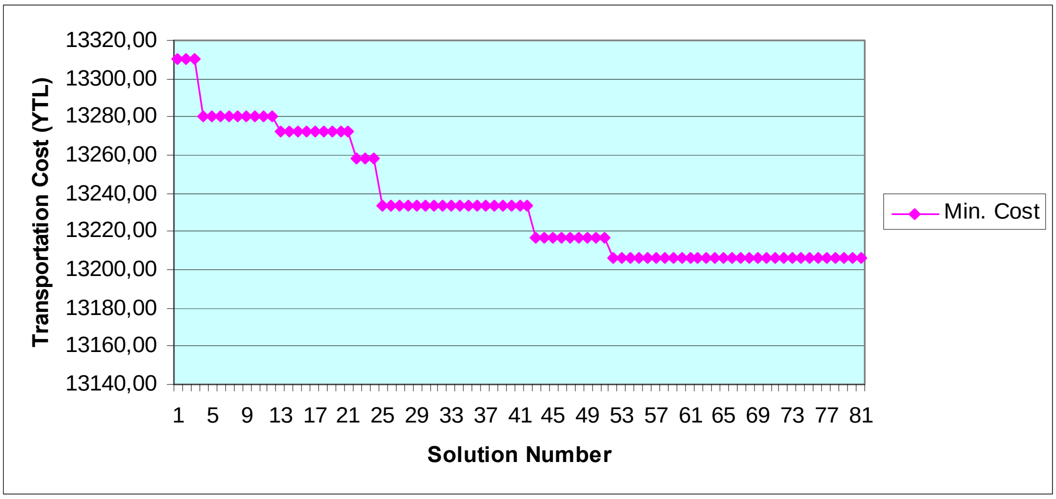


Figure 5. For Model1-2 problem, the variation of transportation costs according to solution number

The speed of the approaching optimum solution of the SA algorithm for the best solution for Model 1-2 was found on the 50th solution number. The algorithm reached 61.7 % improving the value on 50th solution number.

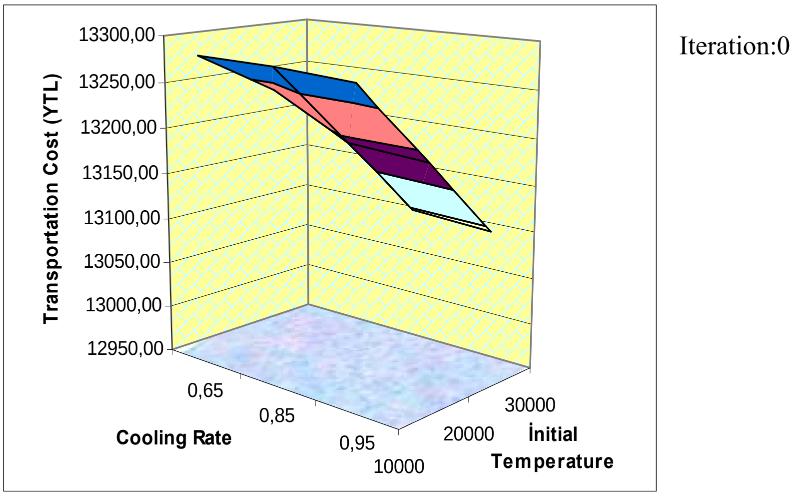
3.4.1.The Analysis of Experiment Design According to SA Algorithm for Model1-2

In order to introduce the model1-2 more explicitly, an experimental design and analysis was applied in this study. During the process of the experimental design, multiple analysis of variance was used in order to determine whether the applied factors are effective on the performance of the SA algorithm. Moreover, whether there is any difference between the levels for these factors was assessed by the Duncan multiple range test.

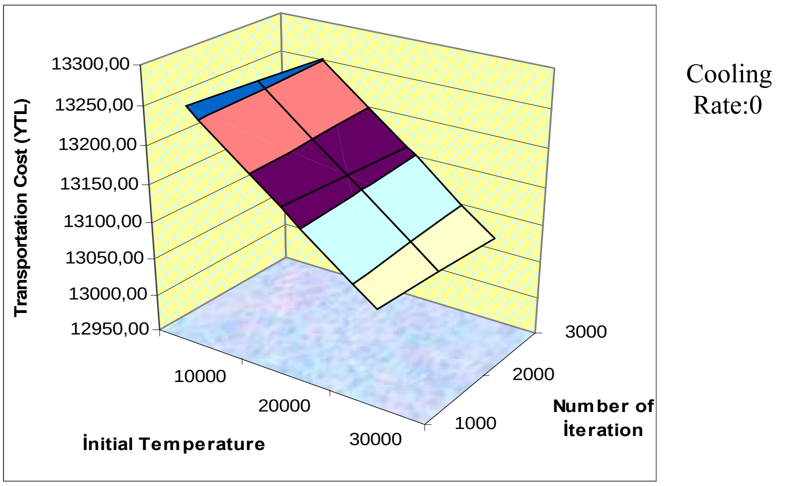
The main effects and maximum two coefficient effects were analyzed with multiple analysis of variance . In the outcome of the Variance Analysis, when P values (significance levels) were analyzed, we see that all the major effects which are considered, except for the minimum temperature (T_1), are effective at a level of $\alpha = 0,05$ relevance on Model-1 of the performance of the SA algorithm. Furthermore, all the two coefficient effects, except for the coefficient effects of the initial temperature (T)-minimum temperature (T1), Cooling rate (r)-minimum temperature (T1), the number of the steps(m)-minimum temperature were found to be relevant.

These results obtained from the multiple variance analysis stress the importance of an annealing plan in order to make the SA algorithm perform well. When we analyzed the results of the Duncan Multiple Spacing Test for the Model 1-2 of SA algorithm, at α=0,05 level of suggestiveness, while low, medium and maximum levels of the minimum temperature revealed no considerable difference; all the combinations of the 3 different levels which were chosen for the parameters of the initial temperature, cooling rate and iteration number caused the SA algorithm to perform differently.

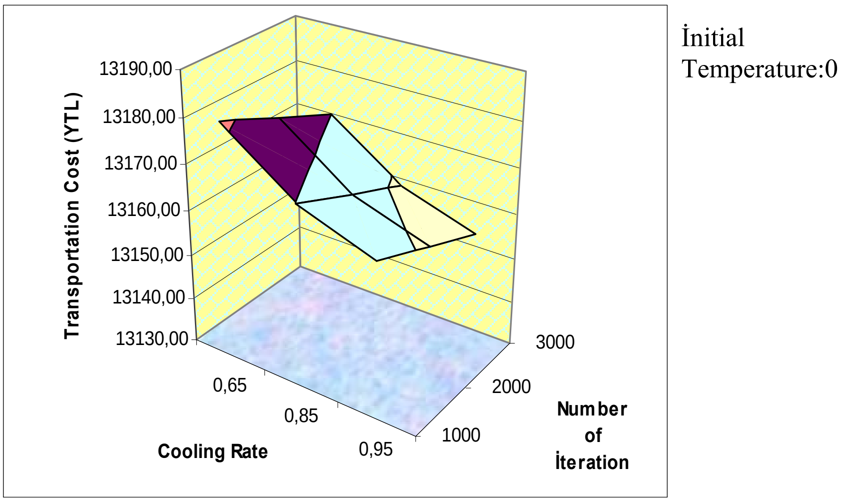
In Figure 6, the levels of the 0.95 cooling rate and 30000 initial temperature (a), the levels of 3000 iteration number, and that of the 30000 cooling rate (b), the levels of 0.95 cooling rate and 3000 iteration number decrease the rate of transportation cost in the YTL currency.



(a)



(b)



(c)

Figure 6. The surface graph of the common effects of Cooling rate and initial temperature(a), Number of iteration and initial temperature(b), Cooling rate and number of iteration(c) on transportation cost

The parameters of the SA Algorithm are defined below according to the Multiple Variance Analysis and the Duncan multiple range test for Model 1-2. With the Duncan multiple range test, in choosing the values of similar parameters, the state of the algorithm functioning in less time is considered. The SA parameters for Model 1-2;

T= 30000, r= 0.95, m= 3000, T_1= 30

3.4.2.The Most Appropriate Alternative Routes and Transportation Cost for Model1-2

In choosing the most appropriate parameters for Model 1-2, the routes which lower the total transportation costs of wood raw materials obtained by using (T= 30000, r= 0.95, m= 3000, T_1= 30) are shown in Table 7.

In this version, as there was no authorization to transport to the Bicik depot, all the wood raw materials, which were stowed, were transported to Kovanlı depot (Figure 7). According to this, the total transportation cost was calculated as 13206.66 YTL.

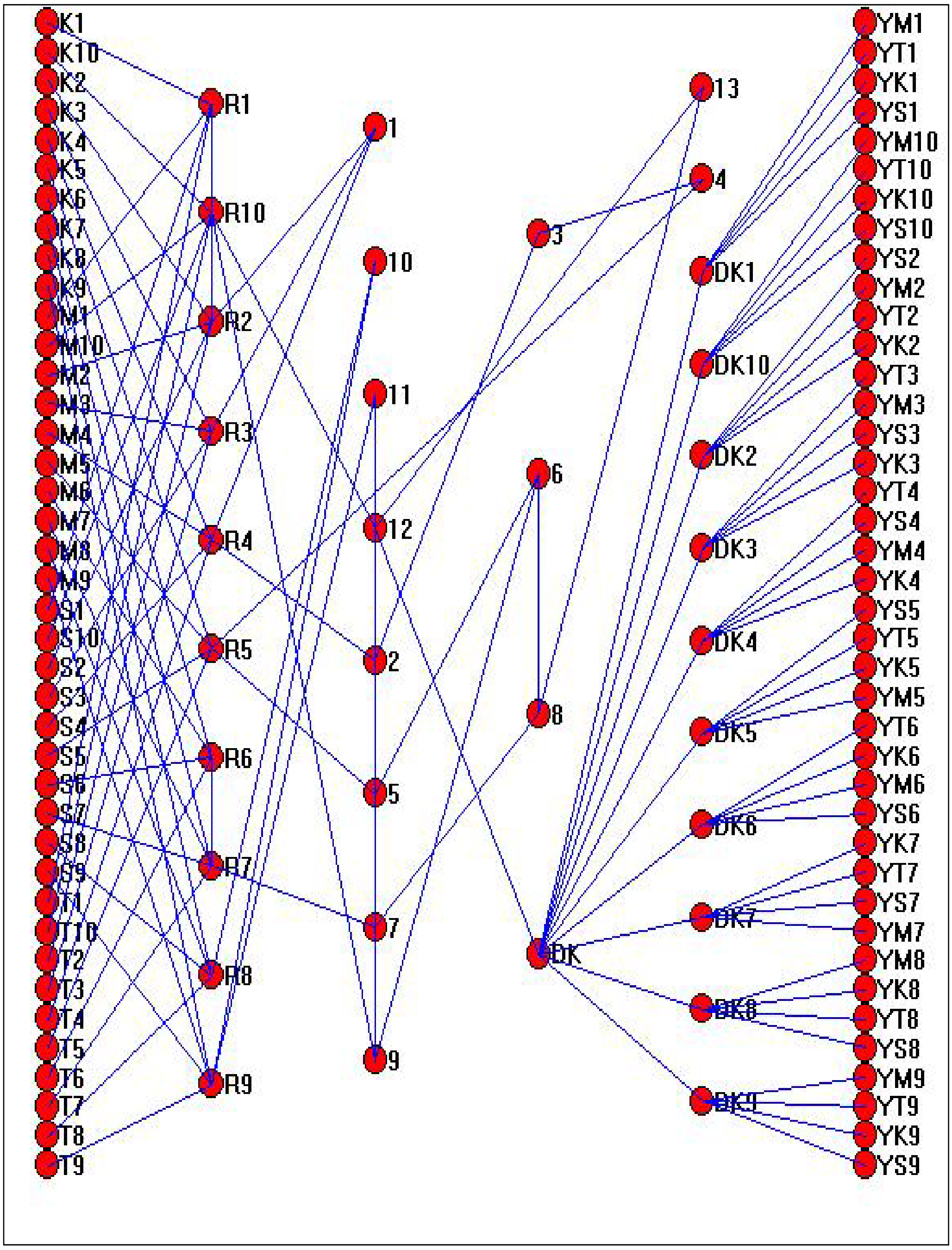


Figure 7. Transportation routes developed for Model1–2

Table 7. The Routes which lower down the transportation cost for each wood raw material to the minimum level for Model 1-2

Raw material Volume (m^3)	Harvest Points	The Best Routes
473.7	T1	T1->R1->R2->1->R4->2->3>4->R5->5->6->9->R10->12>DK>DK1>YT1
540.9	T2	T2->R2->1->R4 ->2->3 ->4->R5->5->6->9->R10->12->DK->DK2->YT2
350.3	T3	T3->R3->1 ->R4->2 ->3 ->4 ->R5->5->6 ->9 ->R10->12->DK->DK3->YT3
84.3	T4	T4 -> R4 -> 2 -> 3 -> 4 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK4 -> YT4
943.0	T5	T5 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK5 -> YT5
83.4	T6	T6 -> R6 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK6 -> YT6
222.8	T7	T7 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK7 -> YT7
308.5	T8	T8 -> R8 -> 10 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK8 -> YT8
547.0	T9	T9 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK9 -> YT9
122.5	T10	T10 -> R10 -> 12 -> DK -> DK10 -> YT10
34.4	S1	S1->R1 ->R2->1->R4->2->3->4->R5->5->6 ->9->R10->12->DK->DK1 -> YS1
114.7	S2	S2->R2->1->R4->2->3 -> 4 -> R5 > 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK2>YS2
202.0	S3	S3->R3->1->R4->2->3 -> 4 > R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK3>YS3

201.4	S4	S4 -> R4 -> 2 -> 3 -> 4 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK4 -> YS4
236.7	S5	S5 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK5 -> YS5
12.6	S6	S6 -> R6 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK6 -> YS6
70.0	S7	S7 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK7 -> YS7
40.6	S8	S8 -> R8 -> 10 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK8 -> YS8
25.9	S9	S9 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK9 -> YS9
31.1	S10	S10 -> R10 -> 12 -> DK -> DK10 -> YS10
58.9	M1	M1->R1->R2->1->R4->2->3->4->R5>5->6->9->R10 -> 12 -> DK ->DK1 ->YM1
10.2	M2	M2->R2-> 1 ->R4->2->3->4-> R5 > 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK2>YM2
37.8	M3	M3->R3->1->R4->2->3->4->R5 -> 5 -> 6 -> 9 -> R10 -> 12 > DK -> DK3 >YM3
31.0	M4	M4 -> R4 -> 2 -> 3 -> 4 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK4 -> YM4
238.6	M5	M5 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK5 -> YM5
25.9	M6	M6 -> R6 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK6 -> YM6
31.6	M7	M7 -> R7 -> 7 -> 8 -> 6 -> 9 -> R10 -> 12 -> DK -> DK7 -> YM7
17.9	M8	M8 -> R8 -> 10 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK8 -> YM8
89.3	M9	M9 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK9 -> YM9
30.7	M10	M10 -> R10 -> 12 -> DK -> DK10 -> YM10
14.5	K1	K1->R1->R2->1->R4->2->3->4->R5->5->6->9->R10->12-> DK ->DK1 -> YK1
13.1	K2	K2-> R2->1->R4->2->3->4->R5->5->6->9->R10->DK->DK2->YK2
13.7	K3	K3->R3->1->R4->2->3->4 -> R5 -> 5 -> 6 -> 9 > R10 -> 12 -> DK -> DK3 >YK3
11.8	K4	K4-> R4-> 2->3->4->R5->5->6->9->R10->12 -> DB->DB4->YK4
47.8	K5	K5 -> R5 -> 5 -> 6 -> 9 -> R10 -> 12 -> DK -> DK5 -> YK5
10.3	K6	K6-> R6->R7->7->8->6->9->R10->12-> DK->DK6->YK6
10.8	K7	K7-> R7-> 7->8->6->9->R10->12-> DK->DK7->YK7
11.8	K8	K8 -> R8 -> 10 -> R9 -> 11 -> 9 -> R10 -> 12 -> DK -> DK8 -> YK8
10.2	K9	K9-> R9->11->9 ->R10 -> 12-> DK->DK9->YK9
15.8	K10	K10 -> R10 -> 12 -> DK -> DK10 -> YK10

3.5. General Discussion on Wood Raw Material Transportation Models

The transportation system elements are generally the factors which are crucial, and adapt their approach according to the cost of the Forest Management in order to operate effectively. For this reason, the design and the optimization of the transportation system became a vital activity for the Forest Managements [1].

The model in which the transportation data of the study was used, was run many times by using predefined parameters of the simulated annealing. As a result of this repetition , the total cost of the transportation varied depending on the the effectiveness of the initial solution. Another reason for encountering different values in the gathered results comes from the software used because we see that whenever it is run, it gives random values to the input. For these reasons, the simulated annealing meta-heuristic method is not an optimum solution method and the fact that it operates with the probabilities helps us explain the different values gathered from the study.

Totally 5377.500 m^3 of log, industrial wood, mine post and paper wood were transported to the Kovanlı depot with lorries over the forest pathways in 2007. According to the accounts of the Anbardağ Forest Enterprise District, the transportation costs of industrial wood raw material was 13.32 YTL (21.32$) per $1m^3$and a total of 71621.64 YTL (114594.62$) was paid for the transportation expenses.

When the values which came out practically as a result of the single choice of the transporters by the management were compared for the model 1-2, we saw that there was saving of 18.45%. Acar [29], stated that if the transportation of Artvin Forest Management Directorate was planned with a LinearBased programmed transportation model on forest pathways, it could save 16% on the costs. For the other model, no comparison could be made as there were only two depots used in this application.

During transportation problems, the duration of search for a solution with the SA for these models lasted about 230-235 seconds. Murray and Church [30], used two meta-heuristic methods of Simulated Annealing and Tabu Search for the operational forest plans. This approach which gives parallel results could reach the outcome in a short time.

4. Conclusion

Two different models were used for the evaluation of the developed model and designed Simulated Annealing Algorithm. Moreover, 405 experiments were performed for each model and 81 experiments which gave the best results were reported.

The factors were evaluated at the significant level of α=0,05. According to this, initial temperature, the iteration number and cooling rate were seen as significant. There was no influence of minimum temperature found. High initial temperature, high rate of iteration number and high cooling rate brought about good results in the model. In this sense, the expected results were obtained.

According to the number of examined solutions, when we compared the 81 experiments in each transportation route, the solutions with the lowest costs which the algorithm found were taken into consideration. It was found that the optimum approaching speed to the solution of SA algorithm could succeed in finding the best solution for the Model 1-1 on the 53rd solution number. With the number of 53rd solution, the algorithm showed a 65.4% improvement. For Model 1-2 the best solution arrived with the 50th solution result. The algorithm showed 61.7% improvement.

In Model 1-1 when it was allowed to use the two forest depots, the total transportation cost was calculated as 11309.52 YTL(18095.23$) by using SA parameters. In Model 1-2 on the condition of one depot usage allowance, the total transportation cost was calculated as 13206.66 YTL(21130.66$) by using SA parameters. For Model-1 on condition that it was allowed to use two depots, the total transportation cost was lowered down 14.45%.

Even if the numeral gains obtained from the study may be seen as low, these values which were obtained in a small area undoubtedly can supply large amounts of savings in larger areas where this kind of planning was carried out.

In planning the new forest roads, the total cost of road-building and its maintenance cost, and transportation cost can be evaluated with Simulated Annealing calculations and with the most appropriate routes the road standards can be choosen.

In future studies, the existing meta-heuristic algorithms related to transportation problems could be compared to the effectiveness of Simulated Annealing Algorithm. Appropriate parameter values for transportation problems can be maintained by using different parametric values of Simulated Annealing Algorithm. The Simulated Annealing can be applied to subtraction problems without dividing.

References

[1] E. Çalışkan, ''The Optimization of Transportation for Wood Raw Material on Forest Road Network by Simulated Annealing'', *PhD Thesis*, 2008, Department of Forest Engineering, Karadeniz Technical University, 148p., Trabzon,Turkey.

[2] E. Çalışkan, N. Şentürk, H.H. Acar, ''Investigation of Hydraulic Constructıon Buildings in Forest Road Using GIS and GPS'', İÜ, *Journal of Forest Faculty*, Series: A, 2006, 56, 2, 177-190p.İstanbul, Turkey.

[3] OÖİKR, "IX. Five Year Development Plan: First Draft", www.ogm.gov.tr 30 Nisan. 2006

[4] M. Demir, ''Impacts, management and functional planning criterion of forest road network system in Turkey''. *Transport Research Part-A*, 2007. 41, 56-68.

[5] R. Pulkki, ''A Spatial Database – Heuristic Programming System for Aiding Decision-Making in Long Distance Transport of Wood'', *Acta Forestelia Fennica,* 1984,188, 1-89.

[6] Z. Shen, J. Session,''Log Truck Scheduling By Network Programming'', *Forest Products Journal*, 1989, Vol.39, No.10, 47-50 p.

[7] E.G. Schuster, L.A. Leafers, J.E. Thompsın, "A Guide to Computer Basde Analytical Tolls for Implementing National Forest Plans", USDA Forest Service, Intermountain Research Station General Technical Report, 1993, INT-296.

[8] E.C. Sullivan, ''Network User's Guide. Spec. Rep. Inst. Transport and Traffic Eng.'' 1974, Berkeley, Universty of California.

[9] J. Sessions,''A Heuristic Algorithm for The Solution of The Fixed and Variable Cost Transportation Problem''. in Proc. of the 1985 Symposium on Systems Analysis in Forest Resources, Dress and Field (eds.). 1985, Society of American Foresters, Dec 9-11, Athens, GA, USA.

[10] M. Kirby, P. Wong, W. Hager, Guide to Tranship model. USDA For. Serv. Pac. Southwest For. Range Exp.Stn. Berkeley, 1981.

[11] P. Wong, ''An empirical evaluation of the proration option of the MINCOST network program''. USDA Forest Service Engineering Field Notes. Washington D.C. 1981, pp.15–22.

[12] A. Weintraub, ''NETCOST, a heuristic approach for roading and forest management planning''. COOP Agrerement Rep., Berkeley, Univ. 1986, 53–57, California,

[13] J. Sessions, W. Chung, and H.R. Heinimann., "New Algorithms for Solving Large-Scale Harvesting and Transportation Problems Including Environmental Constraints". Proceedings of the FAO/ECE/ILO Workshop on New Trends in Wood Harvesting with Cable Systems for Sustainable Forest Management in Mountains, 2003, Ossiach, Austria, June 18-24, 253-258 pp.

[14] H.H. Acar,''A Study on Preparing Forest Transportation Plans on Mountainous Land (The Sample of Kümbet Forest Enterprise District)'', *Turkish Agriculture and Forestry*, 1997, 21, 201-206.

[15] M. Palmgren, M. Ronnqvist, P. Varbrand, ''A Near-Exact Method for Solving the Log-Truck Scheduling Problem'', *Intl. Trans. In Op. Res ,*2004*,* 11, 447–464.

[16] K. Aruga, J. Sessions, A. Akay, ''Heuristics techniques applied to forest road profile''. Japanese Forestry Society, *Journal of Forest* Research*,* 2005,10(2), 83–92.

[17] H. Broman, M. Frisk, M. Rönnqvist, ''Supply Chain Planning of Harvest Operations and Transportation After the Storm Gudrun'', Discussion Papers, Department of Finance and Management Science, Norwegian School of Economics and Business Administration, 2006 No:16, 18 pp.

[18] E. Çalışkan, H.H. Acar, ''An Evaluation About Using Artificial Intelligence Techniques On Wood Raw Material Production'', *Artvin Journal of Forest Faculty*, 2006, 7, 1, 51-60p.

[19] OGM, "General Directorate of Forestry, 2006 year of Döner Sermaye Bütçesi", Rebuplic of Turkey Ministry of Environment and Forestry, OGM/APK Dairesi Başkanlığı, 127 s**.** 2006, Ankara**.**

[20] E.S. Miyata, H.M. Steinhilb, ''Logging System Cost Anaysis-Comparison of Method Used USDA'', Research Paper – NC 208, North Central Forest Experiment Station, Minnesota, USA, 1981,18 pp.

[21] FAO, ''Cost Control in Logging Operations'', FAO Forestry Paper No: 99, 1992, Rome.

[22] A. Akay, ''Minimizing Total Cost of Construction, Maintenance, and Transportation Costs with

Computer-Aided Forest Road Design'', *PhD Thesis*, 2003, 148 pp. Forest Engineering, Oregon StateUniversity,

[23] D. Beasley, ''An Overwiew of Genetic Algorithms''; Part 1, Fundamentals. Universty Computing, 1993, 15: 58-69.

[24] S. Kirkpatrick, C. Gellat, M.Vecchi, ''Optimization by Simulated Annealing''. Science, 1983, 220: 671-680.

[25] E.Z. Başkent, ''Combinatorial Optimization in Forest Mangement Modelling'', *Turkish Journal of Agriculture and Forestry*, 2001, 25, 187-194.

[26] E.Z. Başkent, J.A. Jordan, ''Forest Landscape Management Modelling with Simulated Annealing''. *Forest Ecology and Management*, 2002, 165/1-3, 29-45.

[27] D. Johnson, C. Aragon, L. McGeoch, L and C. Schevan, "Optimization by Simulated Annealing and Experimental Evaluation. Part 1. Graph Partitioning", *Operations Research*, 1989, 37(6): 865-892.

[28] W. Chung and J. Sessions, ''NETWORK 2000: A Program for Optimizing Large Fixed and Variable Cost Transportation Systems'', Proc. of the Eighth Symposium on System Analysis in Forest Resources, Arthaud, G.J. (ed.). Sept 28-30, 2000, Aspen, Colorado.

[29] H.H. Acar, ''Giresun Orman Bölge Müdürlüğü Üretim Araçlarının Teknik ve Ekonomik Açıdan İncelenmesi, *TÜBİTAK Doğa Dergisi*, 1998, 22, 2, 143-150.

[30] A.T. Murray, R.L. Church, ''Heuristic Solution Approaches to Operational Forest Planning Problems'', *Journal of Forest Engineering*, 1993, 9, 31-37.

[31] M.R. Ghaffariyan, K. Stampfer J. Sessions, T. Durston, and C.Kanzian., ,'Road Network Optimization in Cable Yarding Operations Using Network Analysis and Mixed Integer Programming to Minimize Total Cost'', *Journal of Forest Science (*Czech), 2010, 56 (3):137-145.

[32] M.R. Ghaffariyan, H. Sobhani, ''Optimization of an existing forest road network using Network 2000''. *Croatian Journal of Forest Engineering***,** 2007, 28(2):185-193.

Vitae

Erhan Çalışkan. Ass. Prof. Dr (since 2009), Department of Forest Engineering, Faculty of Forestry, Karadeniz Technical University, Trabzon, Turkey. Research interests: Forest Road, Forest Transportation, Simulated annealing, Genetic algorithm, GIS,

H.Hulusi Acar. Prof. Dr (since 2002), Department of Forest Engineering, Faculty of Forestry, Karadeniz Technical University, Trabzon, Turkey. Research interests: Forest Road, Forest Transportation, Forest Mechanization.