DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

OPTIMIZATION FOR SUPPLY CHAIN MANAGEMENT-SCM USING VEHICLE ROUTING PROBLEM-VRP AND AN APPLICATION IN FMCG INDUSTRY

by

Özlem KOÇTAŞ

January, 2006

İZMİR

OPTIMIZATION FOR SUPPLY CHAIN MANAGEMENT-SCM USING VEHICLE ROUTING PROBLEM-VRP AND AN APPLICATION IN FMCG INDUSTRY

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by

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"OPTIMIZATION FOR SUPPLY CHAIN MANAGEMENT-SCM USING VEHICLE ROUTING PROBLEM-VRP AND AN APPLICATION IN FMCG INDUSTRY"** completed by **ÖZLEM KOÇTAŞ** under supervision of **ASST.PROF.DR MEHMET ÇAKMAKÇI** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

Distribution management is an operational level activity for supply chain management. The most important model in distribution management is the vehicle routing problem. A vehicle routing problem involves determining for each vehicle, which of the customers will be visited and what route will be followed so that the total delivery cost is minimised. In today's business environment, the task of optimal routing a fleet of vehicles is becoming an obvious necessity. FMCG is an acronym for Fast Moving Consumer Goods, means 'things you buy on a regular basis at places like your local supermarket'. In the FMCG industry on any given day, many delivery drivers or route sales representatives are on the road making deliveries to the customers. Vehicle routing in this industry is a very large problem and difficult to solve manually. In this thesis we do a vehicle routing application in FMCG industry. Territory Planner is used to optimize the delivery routes.

Keywords: FMCG Industry, GIS, Vehicle Routing Problem

ARAÇ ROTALAMA PROBLEMİ KULLANARAK TEDARİK ZİNCİRİ YÖNETİMİ OPTİMİZASYONU VE HIZLI TÜKETİM ÜRÜNLERİ SEKTÖRÜNDE BİR UYGULAMA

ÖZ

Dağıtım yönetimi, tedarik zinciri yönetimi için operasyonel seviyede bir aktivitedir. Dağıtım yönetimindeki en önemli model araç rotalama problemidir. Araç rotalama problemi toplam masrafı en küçükleyecek şekilde her araç için hangi müşterinin ziyaret edileceği ve hangi rotanın izleneceği kararının verilmesini içerir. Günümüz iş çevrelerinde, araç filolarının optimal olarak rotalanması görevi açıkça çok önemlidir. Hızlı tüketim ürünleri yerel bir marketten düzenli olarak satın aldığınız ürünleri içerir. Hızlı tüketim ürünleri sektöründe gün içinde bir çok dağıtıcı ya da satış temsilcisi müşterilere teslimat yapmak için yoldadır. Araç rotalama bu sektör için büyük bir problemdir ve manuel metotlarla çözümü zordur. Bu tez çalışmasında hızlı tüketim ürünleri sektöründe bir araç rotalama uygulaması yapılmıştır. Dağıtım rotalarını optimize etmek için Territory Planner kullanılmıştır.

Anahtar Sözcükler: Hızlı Tüketim Ürünleri Sektörü, Coğrafi Bilgi Sistemleri, Araç Rotalama Problemi

CONTENTS

Page

CHAPTER ONE

INTRODUCTION

The supply chain encompasses every effort involved in producing and delivering a final product or service, from the supplier's supplier to the customer's customer. Supply Chain Management includes managing supply and demand, sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, and delivery to the customer. Distribution management is an operational level activity for supply chain management.

Logistics and especially the distribution of goods, lie at the heart of business activity. The importance of distribution management motivated intense theoretical work and the development of effcient models and algorithms, which have also been applied to a variety of other scientific and industrial fields. The most important model in distribution management is the vehicle routing problem. (Tarantilis, Diakoulaki & Kiranoudis, 2002)

The Vehicle Routing Problem (VRP) is a key part of daily operations for a wide number of industries such as trucking companies, demand responsive transit, and courier services, to name a few.

Vehicle routing is a choice to find a feasible route for a vehicle. In real world there are many vehicles to route and many stations to visit. Vehicle Routing is a difficult process to perform. It becomes a daunting task as the number of vehicles increases. And VRP solves this case by using different methods such as branch and bound algorithm, savings algorithm and genetic algorithms. The main objective of the VRP is to deliver a set of customers with known demands on minimum cost vehicle routes.

1.1 Purpose of the Study

The purpose of the study is optimizing the delivery routes of Frito Lay Ankara distribution center and decreasing fuel cost of the company. To reach this purpose Territory Planner is used as an optimization tool. To decrease fuel cost a new algorithm is also proposed.

CHAPTER TWO
VEHICLE ROUTING PROBLEM

2.1 Routing Problems

Routing problems have been widely studied during recent years, mainly because of the increasing number of practical applications and the major increase in the costs associated with operating a fleet of vehicles. These problems can be divided into Node Routing Problems and Arc Routing Problems. In node routing problems the demand occurs in the nodes (or vertices) of a graph. An example of this might be a salesman who must visit each city in a country. Arc routing problems have demand on each of the arcs (or edges) of the graph. An example of an arc routing problem might be a postman who must travel along each street in a town. Table 2.1 shows a comparison between arc routing and node routing.

Table 2.1 Arc routing versus node routing

	Arc Routing	**Node Routing**
Type of Tour	Eulerian	Hamiltonian
Where Are Routes Constructed?	Over the arcs	Over the nodes
Type of Problem	Continous	Discrete
Customers Modeled as	Arcs/edges	Nodes/vertices
Examples	Chinese postman problem, rural postman problem (garbage collection, snow removal, mail delivery, street sweeping, etc.)	Traveling salesman problem,vehicle routing problem (transportation of handicapped persons, food distribution)

2.2 The Definition of Vehicle Routing Problem

The most fundamental and well-studied routing problem is the Traveling Salesman Problem (TSP) , in which a salesman is to visit a set of cities and return to the city he started in. The objective for the TSP is to minimize the total distance traveled by the salesman.

The vehicle routing problem (VRP) is a generalization of the TSP in that the VRP consists in determining m vehicle routes, where a route is a tour that begins at the depot, visits a subset of the customers in a given order and returns to the depot. All customers must be visited exactly once and the total customer demand of a route must not exceed the vehicle capacity.

The well-known Vehicle routing problem (VRP) can be defined as the problem of determining optimal delivery or collection routes from a given depot to some geographically dispersed customers subject to operating restrictions. (Ghiani & Improta, 2000)

Vehicle routing problem (VRP) is the generic name given to a large class of problems involving the distribution of goods, services, information or personnel. (Martinhon , Lucena & Maculan ,2004)

Vehicle routing problems arise in many real-life applications within transportation and logistics, such as school bus routing, collection of mail from mail boxes, transportation of handicapped persons, collection of coins from vendor machines, preventive maintenance inspection and food distribution. (Koçtaş& Çakmakçı, 2005)

The VRP is a well known integer programming problem which falls into the category of NP Hard problems, meaning that the computational effort required to solve this problem increases exponantially with the problem size. For such problems it is often desirable to obtain approximate solutions, so they can be found fast enough and are sufficiently accure for the purpose. Usually this task is accomplished by using various heuristic methods,which rely on some insights into the problem nature.

The VRP is also known in the literature as the following problem. Clarke & Wright (1964), described it as the “vehicle scheduling” problem. Dantzig & Ramser (1959), Christofides & Eilon (1969), and Gillet & Miller (1974) call it the “truck dispatching problem”, and Balinski & Quandt (1964) related it to the “delivery” problem.

2.3 Importance of Vehicle Routing

In today's business world, transportation cost typically constitutes more than half of the total logistics costs. This share has experienced a steady increase, since smaller, faster, more frequent, more on time shipments are required as a result of trends such as increased variability in consumer's demands, near-zero inventory production and distribution systems, sharp global-size competition.

The benefits that may be achieved by reducing the transportation costs is of interest to the business at the micro level, and to the country at the macro level. For example, the transportation process involves all stages of the production and distribution systems and represents a relevant component (generally from 10% to 20%) of the final cost of the goods. It should come as no surprise that many people in business and researchers in management science and operations research have shown great interest to the transportation aspect of the logistics activities.

Decreasing transportation costs can be achieved through better utilization of resources such as people, vehicles. One of the most important steps involved in utilizing vehicles efficiently is performing an efficient routing of a fleet of vehicles when they are to pickup/deliver passengers or goods from/to certain points.

Vehicle routing problems are important combinatorial optimization problems occurring in many distribution systems with considerable economic significance. It is estimated that distribution costs account for almost half of the total logistics costs, and in some industries, such as in the food and drink business, distribution costs can account for up to 70% of the value added costs of goods.

Approximately 75% of all the transportation of goods is done by vehicles that also underlines the importance of vehicle routing problems.

On the other hand, it has been estimated that the capacity utilization with load is only 60%, and the vehicles drive 36% of the time empty indicating a significant potential for improvement.

2.4 Objectives of the VRP

In the VRP case, the decisions to be made define order of the sequence of visits to the customers; they are a set of routes. A route departs from the depot and it is an ordered sequence of visits made by a vehicle to the customers, fulfilling their orders.

The most common objective is the minimisation of transportation costs as a function of the travelled distance or of the travel time; fixed costs associated with vehicles and drivers can be considered, and therefore the number of vehicles can also be minimised. Another objective can take into account vehicle effciency, expressed as the percentage of load capacity (the higher, the better). The other common objectives are minimizing total route lenght and minimizing number of routes.

2.5 The Elements of the VRP model

The elements of the VRP define and constrain the model. The elements of the VRP model are: the road network, describing the connectivity among customers and depots; the vehicles, transporting goods between customers and depots on the road network; the customers, which place orders and receive goods. (Rizzoli, Oliverio, Montemanni & Gambardella, 2005)

2.5.1 The Road Network

The road network is represented as a graph, where depots and customers are placed on nodes and the arcs represent the distance, in space and/or time, between two nodes. The road network graph can be obtained from a detailed map of the distribution area on which the depots and the customers must be geo-referenced. Standard algorithms can then be used to find all the shortest routes, with respect to time and distance, between all couple of nodes, in order to build the distance matrix.

2.5.2. The Vehicles

The vehicles and their characteristics also impose constraints on the vehicle routing model. The fleet can be homogeneous, if all vehicles are equal in all their characteristics, otherwise it is said to be heterogeneous. Most real-world fleets are heterogeneous. Mechanical features (length, weight, width, number of axles) and configuration (trailer, semi-trailer, van, etc.) define the access constraints for a vehicle. For instance, a vehicle cannot travel on some arcs of a road network, because of excessive weight or dimensions. Capacity constraints, stating the maximum load to be transported by a vehicle, are also relative to the mechanical features of a vehicle. These are expressed in a unit of measure determined by the transported goods (e.g. litres for fluids, pallets for boxed goods, and also kilograms, cubic metres).

2.5.3 The Customers

Each customer requests a given amount of goods (an order), which must be delivered or collected (picked-up) at the customer location. Time windows during which the customer can be served can be specified. These time windows can be single (one continuous interval) or multiple (eg., delivery is possible only from 9 am to 12 am and from 5 pm to 6 pm). Time windows can be “hard”, when a vehicle cannot arrive later than a given time, but it can wait if arriving early. In such a case, the objective function tries to minimise the distance and the waiting time. On the other hand, when a penalty is paid in case of violation, time windows are said to be “soft”.The vehicle routing model can also include an estimation of the service time at the customer . These times depend on the customer facilities, on the ordered quantity, and on bureaucratic requirements. They are used to compute the delivery time, which is needed to compute the time at which the vehicle is ready to leave for the next customer in its tour.

2.6 Some Practical Aspects of Vehicle Routing Problem

Christofides (1997) explains some practical aspects of Vehicle Routing Problem as follows.

2.6.1 Multiple Depots

Some companies have more than one depot. Depot operations may be autonomous or interdependent. If depot operations are autonomous, the problem will be similar with single depot VRP. In other case each depot cannot be considered in isolation.

2.6.2 Level of Customer Service

Order fulfillment time is one of the most important parameters in a VRP and is a measure of the service level.

2.6.3 Multiple Commodities

In the distribution of gasoline fuel or food, the vehicles can be compartmentalized, so different commodities are stored in segregated compartments. Each customer may require different types of commodity. Such problems involve a knapsack or bin packing aspect.

2.6.4 Different Objectives

Sometimes solving the VRP may be infeasible. This problem is resolved by either hiring more vehicles and/or postponing service to some customers beyond the established service level or into the next period. In this situation the objective may be to minimize: the number of extra vehicles hired, the number of customers not served in the present period, the total distance (or time) traveled.

2.7 Route Characteristics

2.7.1 Mixed Pickup and Delivery

At a minimum, mixing pickups and deliveries complicates capacity calculations. But if the fleet is providing a point-to-point routing service, the entire formulation is altered, possibly requiring a totally separate piece of software.

2.7.2 Randomness

Service fleets in particular (such as appliance repair, utility repair, etc.) encounter considerable uncertainty in how long it takes to serve a stop. This makes it difficult or impossible to plan an entire route in advance.

2.7.3 Driver Specializations

Special skills, such as the ability to repair particular kinds of equipment or drive certain classes of trucks, must be reflected in worker assignments. Driver seniority, commission arrangements and equity considerations can also play a role.

2.7.4 Dynamics

Many fleets are moving away from batch processing and toward real-time service, where visits are scheduled immediately, even when vehicles are already working their routes.

2.7.5 Time Windows

Good customer service comes from scheduling stops when customers want them and meeting the time commitment within a narrow window. However, short of inserting enormous idle time in the schedule and driving far out of the way, perfection in this regard is impossible. Therefore, fleets need tools that can trade service against cost.

2.7.6 Multiple Facilities

When operating from multiple depots, warehouses or plants, the company may need to shift work from location to location, based on work loads or inventory availability.

CHAPTER THREE
VARIANTS OF THE VRP

To make VRP more realistic, several different extensions may be added to the basic model. Examples of such extensions are:

One vehicle may operate successive routes, provided the total time spent on these routes does not exceed the maximum routing time.

There may be more than one depot, in which case the problem also includes the question: which depot serves which client?

Some customers specify the time-window in which they prefer to be visited and this may be one- or two sided.

The vehicle fleet may be homogeneous or heterogeneous.

Demand of each client may be known in advance or may be variable, and the problem may well include not only deliveries but also pickups.

Every extentions may cause different variants of the VRP**.** In the literature is faced many variants of the VRP. According to Toth & Vigo (2001) important variants of the VRP:VRP with Time Windows, VRP with Backhauls, VRP with Pickup and Delivery.

3.1 Capacitated VRP (CVRP)

The classical VRP is defined on a graph $G = (N, A)$ where $N = \{0, . . . , n\}$ is a node set and $A=\{(i, j) : i, j \in N\}$ is an arc set. Node 0 is the depot, the other nodes are the customers. The travel cost between customer i and j is defined by $c_{ij} > 0$ and d_i is the demand for customer i. The vehicles are usually identical, each with a capacity q. The objective is then to design a least cost set of routes, all starting and ending at the depot, where each customer is visited exactly once. The total demand of all customers on a route must be within the capacity q. This classical formulation is often referred to as the capacitated VRP or CVRP. If cij ≠ cji for at least one pair of customers, e.g. due to a one-way road, we have an asymmetric VRP. Capacitated VRP is the simplest and most studied variant of the VRP. (Toth &Vigo, 2001)

3.2 Distance-Constraint VRP

For each route there is a maximum length or maximum time constraint. A nonnegative length, d_{ij} is associated with each arc (i,j) Є A and the total length of the arcs of each route cannot exceed the maximum route length, L. If the vehicles are different, then the maximum route lengths are L_k, k=1,….,K. The objective of the problem is to minimize the total length of the routes or of their duration, when the service time is included in the travel time of the arcs.

3.3 VRP with Time Windows (VRPTW)

In a VRP with Time Windows (VRPTW) each customer i is associated with a time interval [ai, bi], called the time window, and with a time duration, si, the service time. The service of each customer must start within the associated time window, and the vehicle must stop at the customer for s_i. This problem is often common in real world applications, since the assumption of complete availability over time of the customers is often unrealistic. Time windows can be set to any width, from days to minutes, but their width is often empirically bound to the width of the planning horizon. Note that the presence of time windows imposes a series of precedences on visits, which make the problem asymmetric, even if the distance and time matrices were originally symmetric. The objective is to minimize the vehicle fleet and the sum of travel time and waiting time needed to supply all customers in their required hours.

3.4 VRP with Backhauls (VRPB)

In VRPB customers are partitioned into two subsets:Linehaul and Backhaul customers. The vehicle delivers a given quantity of product to Linehaul customers. And the vehicle picks up a given quantity of inbound product from the backhaul customer. If a customer requires both pickup and delivery, it is modeled as two separate customers. And the VRPB with customer precedence, all of the linehaul customers must be served before any backhaul customers in each route. The objective is to find such a set of routes that minimizes the total distance traveled.

3.5 VRP with Pickup and Delivery (VRPPD)

In the VRPPD, each customer i is associated with two quantities d_i and p_i. d_i represents the demand of homogeneous goods to be delivered and p_i represents the demand of homogeneous goods to be picked up at customer i. The transport items are not originally concentrated in the depots, but they are distributed over the nodes of the road network. A transportation request consists in transferring the demand from the pick-up point to the delivery point. When the demand is a transport of goods, sometimes the problem can be simplified, according to the characteristics of the transport process. The objective is to minimize the vehicle fleet and the sum of travel time, with the restriction that the vehicle must have enough capacity for transporting the commodities to be delivered and those ones picked-up at customers for returning them to the depot.

3.6 VRP with Time Windows and Split Deliveries (VRPTWSD)

In VRP we generally assume that a customer's demand must be delivered by a single vehicle. Sometimes it is not realistic that a customer's demand must be delivered by a single vehicle. By allowing deliveries to be split, a customer may be serviced by more than one vehicle. The vehicle routing problem with split deliveries (VRPSD) was introduced by Dror and Trudeau in 1989. They showed how split deliveries could result in savings, both in the total distance traveled and the number of vehicles utilized.

The objective is to minimize the vehicle fleet and the sum of travel time needed to supply all customers.

3.7 Open VRP(OVRP)

OVRP is first mentioned by Schrage (1981). And so far OVRP has been studied by very few people. The OVRP is formulated as the CVRP in terms of objective and constraints. The difference between the OVRP and CVRP is ,vehicles don't return to the depot in OVRP, because the vehicles don't belong to company's distribution center. The vehicles are hired from a third party. The objective is to minimise the number of vehicles (we assume that each vehicle travels exactly one route) and, for a given number of vehicles, to minimise the total distance (or time) travelled by the vehicles.

3.8 Multiple Depot VRP(MDVRP)

A company may have several depots from which it can serve its customers.In MDVRP we assign the customers to depot. Each depot has its own fleet. Each vehicle originates from one depot, service the customers assigned to that depot, and return to the same depot. The objective of the problem is to service all customers while minimizing the number of vehicles and travel distance.

3.9 The Truck and Trailer Routing Problem(TTRP)

Generally the usage of trailers is neglected in VRP. A truck and a trailer is together called a complete vehicle. And a truck without a trailer is called a pure truck. In TTRP two customer type is defined:vehicle customer and truck customer.Because of some restrictions (mountainous area etc) truck customer is only accessible without a trailer.Vehicle customer is accessible with or without a trailer.

The objective of the TTRP consists of finding routes such that the total travel costs are minimized and all the constraints described above are satisfied.(Scheuerer,2005)

3.10 The VRP with Stochastic Demand(VRPSD)

VRP is defined as deterministic, each customers demand is known,vehicles have enough capacity to satisfy all customers' demand on their pre-planned routes. In VRPSD each customer's demand is assumed to follow a given probablity distribution.The objective of the VRPSD is to determine a routing policy which is met at each customer and the distance traveled is minimized.

3.11 Dynamic VRP(DVRP)

All demand is not known before the vehicle starts its route. New orders arrive when vehicle is on route and routes have to be replanned at run time.

CHAPTER FOUR
PERIOD VEHICLE ROUTING

In classical VRPs, typically the planning period is a single day. In the case of the Period Vehicle Routing Problem (PVRP), the classical VRP is generalized by extending the planning period to T days where not all customers require delivery on every day in the period.

The period vehicle routing problem is assembled two classical problems: the assignment problem and the vehicle routing problem. Collection/delivery days have to be assigned to each customer and vehicle routes have to be designed for each day of the period so that the total distribution cost is minimised.

PVRP can also be seen as a multi-level combinatorial optimization problem:

In the first level, the objective is to generate a group of feasible alternatives (combinations) for each customer.

In the second level, one of the alternatives for each customer must be selected, so that the daily constraints are satisfied. Thus the customers must be selected to be visited in each day.

In the third level, the vehicle routing problem is solved for each day.

All papers on the PVRP reported in the literature present heuristic methods. Pioneer work in the PRVP is due to Beltrami & Bodin (1974) and Russell & Igo (1979). Beltrami & Bodin (1974) , present two procedures for the municipal waste collection of the City of New York. In the first, routes are initially created according to the Clarke and Wright (1964) heuristic, and then assigned to days of the week. In the second, clients are randomly assigned to days, and then routes are created using the Clarke and Wright method. Their analysis was limited to accounts that require service either three or six times per week.

Russell & Igo (1979) propose for refuse collection a cluster first-route second algorithm when required service level (number of deliveries within the period) is specified for each customer. In a first step, clients are sequentially assigned to delivery day combinations(in decreasing order of their frequency of service), based on three statistical measures: average distance to the assigned nucleus of points on each day combination, the variance in this average, and the average distance to the nearest point in each nucleus on each day of the week. In a second step, routes are designed following one of the two algorithms: the ‘‘M-tour’’method or the Clarke and Wright heuristic.

More sophisticated heuristics were presented by Christofides & Beasley (1984), Tan & Beasley (1984), Russel & Gribbin (1991), Gaudioso & Paletta (1992), Chao, Golden & Wasil (1995) .

Christofides and Beasley (1984) present the exact formulation of the PVRP and propose a two-phase general heuristic as well as its adaptation to the cases where the underlying daily VRP is replaced by a median problem and a traveling salesman problem. Similarly, good results were obtained in the more recent work of Drummond, Ochi and Vianna (2001), who implemented parallel genetic algorithms.

Baptista, Oliveira & Zuquete (2002) present a study of a real period vehicle routing problem. They proposed a mathematical formulation for Almada’s recycling paper containers problem. With the aid of this formulation an integer linear programming formulation for Frito Lay’s period vehicle routing problem is proposed and also new constraints is added.

4.1 Frito Lay's Period Vehicle Routing Problem

The period considered is a two weeks period. (six working days in a week). 15 different service patterns are defined for the problem. Visits occur once, two times or four times in 12 working days. The pattern set can be seen in Appendix A.

It is assumed that for all customers; service time, distance from one customer to another, allowable service patterns and demand are known.

Fixed costs (independently of kilometers driven):It is consisted of the sum of purchase price, insurance, depreciation.

Variable costs **(** related with the distance driven) : It is consisted of the sum of fuel, oil, tires and tubes, and repairs and replacement parts.

$N = \{i:i=1,2,3,\ldots\ldots,3643\}$ the set of customers
$i = 0$, the depot
$R = \{r:r=1,\ldots.,17\}$number of vehicles
$T=12$ number of days within the period $(t=1,2,3,4,5,6,8,9,10,11,12)$
q_i = number of packages to be delivered to customer i for each visit
$Q= 160$ packages vehicle capacity
$D = 8$ hours max time of each route
d_{ij} = distance from i to j
$v=40$ (km/hour) average vehicle speed
$e=16$ YTL fixed cost for each vehicle
$\beta= 0,65$ YTL route cost per km
s_i= service time

- Desicion variables

$$x_{ik}=\begin{cases}1 \quad if \ \ pattern\ k\ is\ chosen\ \ for\ customer\ i \\ 0\ otherwise\end{cases}$$

$$u_{ijtr}=\begin{cases}1 \quad if \ \ vehicle\ r\ goes\ \ from\ i\ to\ \ j\ on\ day\ t \\ 0\ otherwise\end{cases}$$

$$\text{Min} \quad \sum_{t=1}^{T}\sum_{i=0}^{n}\sum_{j=0}^{n}\sum_{r=1}^{R}\beta.d_{ij}.u_{ijtr} + e.r \qquad (1)$$

s.t

$$\sum x_{ik} = 1 \qquad (2)$$

$$\sum u_{iptr} = \sum u_{pjtr} \quad \forall i, p, j \in N \qquad (3)$$

$$\sum_{j=1}^{n} u_{ijtr} = \sum_{j=1}^{n} u_{jitr} \leq 1 \quad for\ i = 0 \qquad (4)$$

$$\sum_{k=1}^{R}\ \sum_{i=0, j\neq i}^{n} u_{ijtr} = 1 \quad for\ \ j \in N \qquad (5)$$

$$\sum_{i=1}^{n} q_{it}\left(\sum_{j=0}^{n} u_{ijtr}\right) \leq Q \qquad (6)$$

$$\sum_{i=0}^{n}\sum_{j=0}^{n}\left(\frac{d_{ij}}{v} + s_i\right) u_{ijtr} \leq D \qquad (7)$$

Eq. (2) ensures that a pattern is chosen for each customer.

Eq. (3) ensures that any vehicle that visits a customer must also leave it.

Eq. (4) makes sure every route starts and ends at the depot.

Eq. (5) define that every customer node can be visited only once by one vehicle.

Eq. (6) is the vehicle capacity constraints.

Eq. (7) is the allowable maximum time of each route.

The formulation is involved 2708118768 variables u_{ijtr}, and 54645 variables x_{ik}, it is not possible to find a solution within acceptable computer time using a solver such as LINGO. In this thesis the solution of the Frito Lay's period vehicle routing problem is obtained by using Territory Planner.

CHAPTER FIVE
SOLUTION TECHNIQUES OF THE VRP

Table 5.1 shows a brief history of vehicle routing problem.

Table 5.1 A brief history of vehicle routing (Golden et all., 2002, p.34).

Decade	Events
1950s	The VRP is formulated as an integer program. Some small problems (10 to 20 customers) are solved.
1960s	Early route-building heuristics (e.g., Clarke and Wright, 1964) are proposed. 2-opt and 3-opt are applied to the VRP (Christofides and Elion,1969) Some problems with 30 to 100 customers are solved.
1970s	A number of two-phase heuristics are proposed (e.g., Gillet and Miller,1974) Computational efficiency becomes an issue (e.g., Golden, Magnati, and Nguyen, 1977) Some larger problems (100 to 1000 customers) are solved. Some problems with 25 to 30 customers can be solved using optimal methods.
1980s	Math programming-based procedures are proposed(e.g., Fisher and Jaikumar,1981) Interactive (man-machine) heuristics are developed(e.g., Cullen, Jarvis, and Ratliff, 1981) Some problems with approximately 50 customers can be solved using optimal methods.
1990s	Metaheuristics are applied to the VRP. Some problems with 50 to 100 customers can be solved optimality (Fisher,1995)

There are several classifications of VRP solution techniques in the literature. Mainly solution techniques can be classified as three section:

1. Exact Approaches
2. Heuristics
3. Meta-heuristics

Fisher & Jaikumar(1981) are classified existing heuristics related to VRP into four classes.

1.Tour building heuristics
2.Tour improvement heuristics
3.Two-phase methods
4.Incomplete optimization methods

Another classification for heuristics can be seen as follows:

1.Cluster first, route second procedures
2.Route first, cluster second procedures
3.Savings or insertion procedures
4.Improvement or exchange procedures
5.Exact procedures
6.Interactive optimization

Laporte ,Gendreau, Potvin, & Semet (2000) divided heuristics for the VRP into two parts:classical and modern heuristics.(The second part is devoted to tabu search heuristics which have proved to be the most successful metaheuristic approach .)

1.Classical heuristics

Two main techniques are used for constructing VRP solutions: merging existing routes using a savings criterion, and gradually assigning vertices to vehicle routes using an insertion cost.

Savings algorithms
Sequential improvement methods
The sweep algorithm
Petal algorithms
Cluster-first, route-second algorithms
Improvement heuristics

2.Tabu search heuristics

Taburoute

Taillard's algorithm

Xu and Kelly's algorithm

Rego and Roucairol's algorithm

The adaptive memory procedure of Rochat and Taillard

The granular tabu search of Toth and Vigo

5.1 Exact Approaches

This approach proposes to compute every possible solution until one of the bests is reached.

5.1.1 Branch and Bound (up to 100 nodes)

A branch and bound algorithm uses a divide and conquer strategy to partition the solution space into subproblems and then optimizes individually over each subproblem. Using branch and bound, we initially examine the entire solution space S. In the processing or bounding phase, we relax the problem. In so doing, we admit solutions that are not in the feasible set S. Solving this relaxation yields a lower bound on the value of an optimal solution.

Since all the VRP variants are NP-hard, their combinatorial complexity makes them intractable as soon as the search space becomes too large, and in vehicle routing this happens in practice when there are a few dozens of customers to serve.Thus,heuristic and metaheuristic methods are the only feasible way to provide solutions for industrial scale problems.

5.2 Heuristics

Heuristic methods perform a relatively limited exploration of the search space and typically produce good quality solutions within modest computing times.

5.2.1 Constructive Methods (Tour Building)

These methods begin with infeasible assignments then, gradually build a feasible solution while keeping an eye on solution cost, but do not contain an improvement phase.

5.2.1.1 Savings

Clark & Wright (1964): The Clarke and Wright savings algorithm is perhaps the most widely known heuristic for the VRP. It applies to problems for which the number of vehicles is a decision variable and it works equally well for directed or undirected problems. A parallel and a sequential version of the algorithm are available.

The savings algorithm is an exchange procedure in the sense that at each step one set of tours is exchanged for a better set. Initially, it is supposed that every demand point is supplied individually by a separate vehicle. Instead of using two vehicles to service nodes i and j using only one vehicle provides obtaining a savings s_{ij} in travel distance.

$s_{ij} = (2\,c_{1i} + 2\,c_{1j}) - (c_{1i} + c_{1j} + c_{ij})$ s:savings

$= c_{i1} + c_{1j} - c_{ij}$ c_{ij}: cost of to go from node i to node j

For every possible pair of tour end points i and j there is a corresponding saving s_{ij}. Order these savings from largest to the smallest starting from the top of the list, link nodes i and j with maximum savings s_{ij} unless the problem constraints are violated.

5.2.2 2-Phase Algorithms

The vehicle routing problem is decomposed into its two natural components:

1-Clustering of nodes into feasible routes
2-Actual route construction with possible feedback loops between two stages.

5.2.2.1 Cluster-First, Route-Second Algorithms

Fisher & Jaikumar (1981): The Fisher and Jaikumar algorithm is probably the best known cluster-first, route-second algorithm. Instead of using a geometric method to form the clusters, it solves a Generalized Assignment Problem (GAP).

The Sweep Algorithm: The sweep algorithm is applied to planar instances of the VRP. Feasible clusters are initially formed by rotating a ray centered at the depot. A vehicle route is then obtained for each cluster by solving a TSP. Some implementations include a post-optimization phase in which vertices are exchanged between adjacent clusters, and routes are reoptimized. This algorithm is efficient for problems of up to about 250 nodes. The solution is constructed in two stages. First nodes are assigned to vehicles, then the routes are constructed. Given the rectangular coordinates for each node, the polar coordinates may be calculated. The depot is taken as the central point and the field is swept clockwise or counterclockwise. Demand nodes are added to the route as they are swept by the ray. If the capacity of a vehicle restricts from adding new nodes to the route, a new vehicle is considered to be routed through the next nodes. This procedure is repeated until no nodes are left over**.** Sweep algorithm is commonly attributed to Gillett & Miller (1974).

The Petal Algorithm: A natural extension of the sweep algorithm is to generate several routes, called petals, and make a final selection by solving a set partitioning problem**.**

5.2.2.2 Route- First, Cluster- Second Algoritms

The route-first cluster-second heuristics find the shortest route that visits all the demand points through solving a traveling salesman problem,then break this route into a set of shorter routes, each to be traversed by one vehicle then the routes are found so that they are feasible with respect to the vehicle capacity constraints and any other side constraints on the route structure or lenght.

5.3 Meta-Heuristics

As noted by Laporte & Semet (2000) , heuristics perform a limited exploration of the search space, in a relatively short computation time, while metaheuristics follow the principles of intensification and diversification in their search. Intensification pushes towards a much more detailed exploration, in the most promising areas of the search space, while diversification aims to avoid being locked up in local minima, but at the expense of computational speed.

5.3.1 Genetic Algorithms (GA)

Genetic Algorithms are perhaps the most widely known type of Metaheuristic Algorithms, and receiving remarkable attention all over the world.

Genetic Algorithms are computer procedures that employ the mechanics of natural selection and natural genetics to evolve solutions to problems.

A population containing a number of trial solutions each of which is evaluated (to yield a fitness) and a new generation is created from the better of them. The process is continued through a number of generations with the aim that the population should evolve to contain an acceptable solution. GAs are characterised by representing the solution as an (often fixed length) string of digital symbols, selecting parents from the current population in proportion to their fitness (or some approximation of this) and the use of crossover as the dominate means of creating new members of the population. The initial population may be created at random or from some known starting point.

Genetic algorithms work with a population of candidate solutions instead of just a single solution, so they make a multiple way search simultaneously. Each individual represents a potential solution for the problem.

The creation of a new generation of individuals involves three major steps or phases:

The selection phase

The recombination or reproduction process

The mutation

Generally, there are three steps to found a genetic algorithm model:

• Specify the chromosomes

• Specify fitness function

• Determine the mutation and/or crossover strategy to guide the optimization process

5.3.2 Tabu Search (TS)

Tabu search is a local search-based metaheuristic that has been successfully applied to a widespread variety of combinatorial optimization problems.

The basic tabu search guides the search to avoid getting trapped in local optima by moving at each iteration from a solution s to the best possible neighbor solution $\bar{s}$, even if it causes a deterioration in the objective value. To prevent the search from cycling, attributes of recently visited solutions are memorized in a tabu list for a number of iterations (tabu duration). Neighbor solutions of s containing such an attribute are considered temporarily tabu or forbidden, unless they fulfill a so-called aspiration criterion.

Tabu search based algorithms have some common components such as a neighborhood definition, short term memory, long term memory and an aspiration criterion.

Neighborhood: It can be defined in terms of a move that transforms one solution to another. The neighborhood N(s) of a solution s is specified by all possible solutions that can be obtained by applying one of the following transformations to s:

- Shift of consecutive nodes to existing tours or new sub-tours.
- Swap of two subsets of nodes between two existing tours.
- Sub-tour root refining.

Short-term memory: Short-term memory restricts the search from revisiting solutions that were considered previously and to avoid the search process from cycling between subsets of solution.

Long-term memory:to diversify the search long-term memory is implemented and a penalty term is added to the evaluation function whenever a move leads to an increase in the current objective function value.

Aspiration criterion: It is a mechanism for overriding short-term memory and long term memory.

5.3.3 Simulated Annealing (SA)

Simulated annealing is a metaheuristic for the global optimization problem, namely locating a good approximation to the global optimum of a given function in a large search space. The SA metaheuristic uses the local search, but also accepts non improving neighbors according to a function of a temperature parameter which depends on the deterioration in the cost function.

It is based on an analogy from the annealing process of solids, where a solid is heated to a high temperature and gradually cooled in order for it to crystallize in a low energy configuration. SA can be seen as one way of trying to allow the basic dynamics of hill-climbing to also be able to escape local optima of poor solution quality.

CHAPTER SIX
SALES TERRITORY DESIGN

Territory design is the problem of grouping small geographic areas called basic areas (e.g. counties, zip code or company trading areas) into larger geographic clusters called territories in such a way that the latter are acceptable according to relevant planning criteria. These criteria can either be economically motivated (e.g. average sales potentials, workload or number of customers) or have a demographic background (e.g. number of inhabitants, voting population). Moreover spatial restrictions (e.g. contiguity, compactness) are often demanded. In the literature often the term alignment instead of design is used.Territory design and management is one of the most critical, but least automated aspects of the companies.

Sales territory design consists of decisions about assigning customers/prospects to specific salespeople, determining geographical design of the salesperson's work unit, deciding visit frequency, and setting other necessary parameters to provide each salesperson with an opportunity to perform well. The importance of properly designed sales territories is recognized by both managers and sales management researchers. Poor designs negatively impact salesperson performance and sales organization effectiveness by limiting the salesperson's opportunity to perform and suboptimizing the deployment of expensive selling resources.(Baldauf, & Cravens, 1999)

Faulty decisions in territory design prevent optimal utilization of expensive selling efforts, and may negatively impact salespeople's behavior, and work results. Poor territory designs will have a negative impact on salesperson morale, result in inadequate market coverage, and complicate management evaluation and control.
(Piercy, Low, & Cravens, 2004)

6.1 Commonly Used Criterias for Sales Territory Design

According to (Kalcsics, Nickel, & Schröder, 2005) commonly used criterias for sales territory design is as follows.

6.1.1 Organizational Criteria

6.1.1.1 Number of Territories

Often, the number of districts to be designed is predetermined by the sales force size designated by the company or planner. In case the size is not self–evident, several methods are proposed to compute suitable numbers.

6.1.1.2 Basic Areas

Sales territories are in most cases not designed based on single customers.Typical examples for basic areas are counties, zip code areas, predefined prospect clusters or company trading areas.

6.1.1.3 Exclusive Assignment

In most applications basic areas have to be exclusively assigned to a territory. This requirement is motivated by several factors. Most notably, unique allocations result in transparent responsibilities for the sales representatives avoiding contentions among them and allowing for the establishment of long–term customer relations.

6.1.1.4 Locations of Sales Representatives

Since salesmen have to visit their territories regularly, their location, e.g. office or residence, is an important factor to be considered in the territory design process.

6.1.2 Geographical Criteria

6.1.2.1 Contiguity

Territories should be geographically connected.

6.1.2.2 Accessability

Often a good accessibility of territories, e.g. to highways is required. Moreover, sometimes non–traversable obstacles like rivers or mountain ranges have to be accounted for.

6.1.2.3 Compactness

In most applications, compact territories are an important design criterion. One way to improve a salesman’s efficiency is to reduce his unproductive travel time. Compact territories usually have geographically concentrated sales activity, therefore less travel, more selling time and hopefully higher sales (better service levels). In other words, the term compactness expresses the desire for territories with minimal total travel times

6.1.3 Activity–related Criteria

6.1.3.1 Balance

This criterion expresses a relation of territories among each other and is motivated by the desire of an even treatment of all sales persons for example in order to evenly distribute workload or travel times among the sales persons or for reasons of fairness in terms of potential prospects or profit.

6.1.3.2 Maximizing Profit

Especially for sales companies, profit is a major aspect in the planning process. Generally a limited resource effort is available and has to be allocated in a profit–maximizing way amongst a number of sales entities such as customers or prospects.

6.2 Some Guidelines For Designing Territories

6.2.1 Sufficient Potential

With insufficient potential, a salaried salesperson will not be used effectively, and commissioned salespeople will leave the company for greener pastures

6.2.2 Reasonable Size

Is a salesperson's time being spent traveling or making face to face sales calls?

6.2.3 Adequate Coverage

Is the salesperson able to service all accounts and able to meet new prospects?

6.2.4 Minimum Impediments

Try to set territories such that rivers, mountains, railroads, etc. set the borders of territories rather than run through the middle.

6.3 Significant Effects of Effective Territory Design (Koçtaş & Çakmakçı, 2005)

- Align resources against the most attractive customer and prospect opportunities
- Balance workload and opportunity for salesmen and route chiefs
- Maximize time in front of customers by minimizing travel time
- Minimize disruption of existing customer relationships

- Minimize field personnel relocation
- Assure customer acceptance
- Reduced selling cost

CHAPTER SEVEN
ROUTING VEHICLES IN THE REAL WORLD

Transportation planning is very important for reducing logistics costs and raising logistics efficiency. In transportation planning process, routes are determined and vehicles are scheduled and dispatched. However, in the majority of enterprices in Turkey, transportation planning managed by experienced operators/drivers. Routes typically are constructed using paper maps and colored pins which represent customers. The operators are often exposed to exceptionally hard working conditions with the increasing routes and customers. It takes long time to make vehicle routing decisions and the actual results are perhaps unideal. Hence, it is very important to have an automatic decision making system in place of operators to route and schedule vehicles.

The vehicle routing problem is one of the most studied problems in the field of operations research. But most of the solution techniques are not applicable to real-world routing problems. Real-world vehicle routing problems can have enormous size and several problems can be only solved using a vehicle routing package. The solution may be not optimally, but at least heuristically.

The rapid development of computer technology and the introduction of Geographic Information Systems (GIS) have been aiding the development of commercial packages. The usage of the packages is increased from day to day.

Commercial software packages geocode and map customers' locations to vehicles, assigns customers to vehicles, determines the best sequence of deliveries for each vehicle so that all customers are serviced and the total distance travelled by the fleet is minimized. Vehicle routing softwares can also integrate with ERP systems.

Generally the construction of vehicle routes in vehicle routing softwares is a multi-step process. This process usually involves creating an initial solution and then improving the initial solution.

It is said that the algorithms which is using by most packages are a combination of heuristics and route improvement algorithms. However, vendors generally do not clarify the algorithms which are used by the softwares. The algorithm which is used by Roadnet transportation suite(Territory Planner) is not known clearly. The only information about the algorithm is, it is a heuristic. The algorithm is designed and tailored to optimize costs. (Hall, 2004)

After the initial routes are constructed, the routes can be edited manually. The user can drag and drop customers between routes. This process is called as fine tuning.

7.1 Geographic Information Systems(GIS)

GIS technology has been developing steadily since the 1960s. As the technology has matured, become more user-friendly, and costs have decreased, GIS applications have spread.

A GIS is a database management system that facilitates the storage, retrieval, manipulation and analysis of spatial and temporal data and its display in the form of maps, tables and figures. The information in a GIS describes entities that have a physical location and extent in some spatial region of interest, while queries involve identifying these entities based on their spatial and temporal attributes and relationships between entities. Geographic data refers to spatial data in terms of their position with respect to a known co-ordinate system, their attributes (which are unrelated to their position) and their spatial inter-relationships with one another. (what is gis?, n.d)

“A GIS is a computer system specifically designed to store, retrieve, and analyze geographically referenced information.”(what is gis?, n.d)

GIS links location to information (such as people to addresses, buildings to parcels, or streets within a network) and layers that information to give you a better understanding of how it all interrelates. You choose what layers to combine based on your purpose. (what is gis?, n.d)

7.1.1 How GIS Works

A GIS stores information about the world as a collection of thematic layers that can be linked together by geography.

7.1.1.1 Geographic References

Geographic information contains either an explicit geographic reference, such as a latitude and longitude or national grid coordinate, or an implicit reference such as an address, postal code or road name. An automated process called geocoding is used to create explicit geographic references (multiple locations) from implicit references (descriptions such as addresses). These geographic references allow you to locate features, such as a business or forest stand, and events, such as an earthquake, on the earth's surface for analysis.

7.1.1.2 Vector and Raster Models

GIS work with two fundamentally different types of geographic models - the "vector" model and the "raster" model. In the vector model, information about points, lines, and polygons is encoded and stored as a collection of x,y coordinates. The location of a point feature, such as a bore hole, can be described by a single x,y coordinate. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as sales territories and river catchments, can be stored as a closed loop of coordinates.

The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals. The raster model has evolved to model such continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture.

7.1.2 Components of a GIS

A working GIS integrates five key components: hardware, software, data, people, and methods.

7.1.2.1 Hardware

Hardware is the computer on which a GIS operates. Today, GIS software runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations.

7.1.2.2 Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. Key software components are:

- Tools for the input and manipulation of geographic information
- A database management system (DBMS)
- Tools that support geographic query, analysis, and visualization
- A graphical user interface (GUI) for easy access to tools

7.1.2.3 Data

Possibly the most important component of a GIS is the data. Geographic data and related tabular data can be collected in-house or purchased from a commercial data provider. A GIS will integrate spatial data with other data resources and can even use a DBMS, used by most organizations to organize and maintain their data, to manage spatial data.

7.1.2.4 People

GIS technology is of limited value without the people who manage the system and develop plans for applying it to real-world problems.

7.1.2.5 Methods

A successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization.

7.1.3 GIS Tasks

General purpose GISs essentially perform six processes or tasks: input, manipulation, management, query and analysis, visualization.

7.1.3.1 Input

Before geographic data can be used in a GIS, the data must be converted into a suitable digital format. The process of converting data from paper maps into computer files is called digitizing.

Modern GIS technology can automate this process fully for large projects using scanning technology. Today many types of geographic data already exist in GIS compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

7.1.3.2 Manipulation

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with your system. For example, geographic information is available at different scales (detailed street centerline files and postal codes at a regional level). Before this information can be integrated, it must be transformed to the same scale (degree of detail or accuracy).

This could be a temporary transformation for display purposes or a permanent one required for analysis. GIS technology offers many tools for manipulating spatial data and for weeding out unnecessary data.

7.1.3.3 Management

For small GIS projects it may be sufficient to store geographic information as simple files. However, when data volumes become large and the number of data users becomes more than a few, it is often best to use a database management system (DBMS) to help store, organize, and manage data.There are many different designs of DBMSs, but in GIS the relational design has been the most useful. In the relational design, data are stored conceptually as a collection of tables. Common fields in different tables are used to link them together.

7.1.3.4 Query and Analysis

Once you have a functioning GIS containing your geographic information, you can begin to ask simple questions such as

- Who owns the grocery on the corner?
- How far is it between two places?

And analytical questions such as

- Where are all the sites suitable for building new houses?
- What is the dominant soil type for pine forest?

GIS provides both simple point-and-click query capabilities and sophisticated analysis tools to provide timely information to managers and analysts alike. GIS technology really comes into its own when used to analyze geographic data to look for patterns and trends and to undertake "what if" scenarios. Modern GISs have many powerful analytical tools, but two are especially important.

Proximity Analysis: How many houses lie within 100 m of this water main? , what is the total number of customers within 10 km of this store?

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.

Overlay Analysis; the integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership with tax assessment.

7.1.3.5 Visualization

For many types of geographic operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating geographic information. While cartographers have created maps for millennia, GIS provides new and exciting tools to extend the art and science of cartography. Map displays can be integrated with reports, three-dimensional views, photographic images, and other output such as multimedia.

7.1.4 Applications of GIS

The routing of vehicles and the management of logistics operations in any company that services a fairly large geographical area can easily become quite a very complex task. The task can be simplified by the applying Geographic Information Systems, which automatically reduce the complexity by bringing out subtle geographic patterns and relationships that can form the basis of good decisions. GIS can help streamline logistics related business processes like inventory management, fleet/truck management and warehousing applications. In each case as is evident, geography is the key to cutting costs. Geography determines which truck will go to or be able to service how many address. Geography determines the time taken by the distributor to get new stocks to the retail outlet. Geography determines how much stock can be transported to the truck in one trip from the warehouse to the truck.

Transportation network management is one of the fastest growing areas for GIS technology. Governments are creating GIS applications for infrastructure planning and analysis, safety analysis, environmental impact assessment, construction planning and management, landuse planning, project engineering, snow plow route analysis, and emergency response management. In addition, vehicle routing applications, especially involving commercial fleets, seem to be particularly popular.

In the literature there are several papers about GIS aided VRP solutions: Keenan(1998), Tarantilis & Kiranoudis(2002), Gayialis & Tatsiopoulos(2004), Tarantilis, Diakoulaki & Kiranoudis(2004)

Figure 7.1 shows an example of GIS based decision support model for vehicle routing.

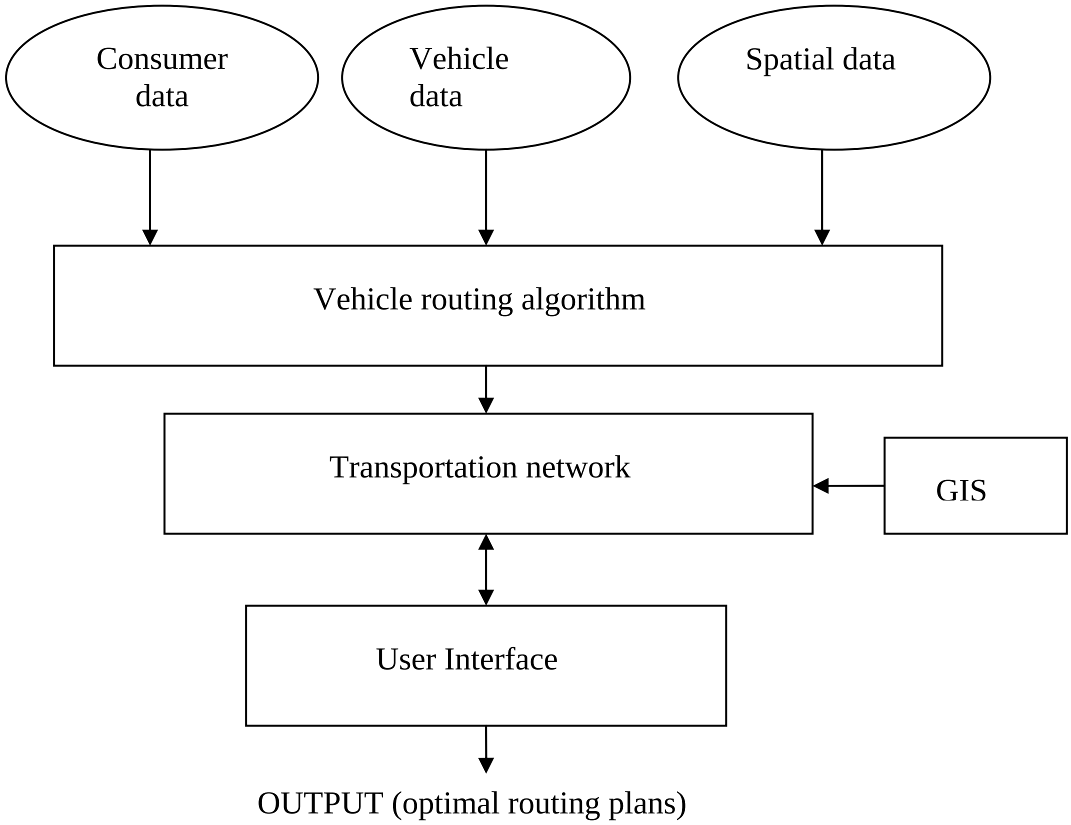


Figure 7.1 Gis based decision support model for vehicle routing

The other GIS applications are: land management/conservation, resource management, emergency services/disaster response, medical and health, public interest, law enforcement, military, commercial/private sector, information, highway, municipal/local government.

7.2 Territory Planner

Territory planner is a module of Roadnet Transportation Suite. Roadnet Transportation Suite composed of four parts: Territory Planner, Roadnet and FleetLoader and MobileCast.

Territory Planner is a territory and route design tool that allows you to create well defined territories and routes. Historical data including delivery days, open/close times, preferred delivery times, volume and geographic location is used to create optimized and balanced territories, routes and stop sequences. All within an easy-to use interface that allows re-routes to occur when they should.

Roadnet, a tactical daily routing tool, allows you to optimize and balance delivery profitability and customer service through routing efficiency. Using advanced industry algorithms and custom routing passes, you can create multiple intelligent route plans faster-maximizing investment in your fleet.

FleetLoader analyzes and optimizes beverage SKUs for loading of both bay or bulk vehicles. Multiple loading strategies can be employed to meet the needs of all delivery types and warehouse requirements. Easy picking, loading and check out are now possible with FleetLoader.

MobileCast, an enterprise-wide pickup and delivery management solution, utilizes a powerful dispatch and tracking software application, wireless networks, and support for multiple mobile devices to provide real-time route visibility for increased operational efficiencies.

The opening screen of Roadnet transportation suite can be seen below Figure 7.1

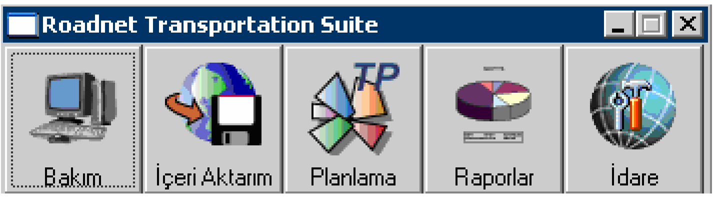


Figure 7.1 Opening screen of roadnet transportation suite

The relationship between roadnet transportation suite’s modules is showed in Figure 7.2

Figure 7.2 The relationship between roadnet transportation suite’s modules

In the application Territory Planner is used to solve Fritolay’s territory design and vehicle routing problem.

Territory Planner, is a strategic planning tool,which allows you try scenarios. Rerouting can be easily perform, changing some of the parameters without losing your existing routes. Territory Planner can be used to determine the results of adding or eliminating trucks on the road.Once new routes are created , many tools can be used and reports included in Territory Planner to analyze and change new routes as needed.

Modules included in the Territory Planner are : Maintenance, import, territory planner, reports, administration.

The Maintenance module comprises all of the information about business locations (depots, locations or delivery customers, etc.), employees, equipment (tractors,trailers, straight trucks, etc.) and how that information will be used when planning and creating routes. The Maintenance module will be used initially to set up information, and then regularly to keep the information in the current system. For example, if you acquire a new type of delivery equipment and are using it to deliver a product, you must enter information about the new piece of equipment so that you have accurate data in the computer system.The Maintenance module in the Roadnet Transportation Suite allows you to set up and maintain the data in the system.

The toolbar’s of Territory Planner can be seen Table 7.1-7.2 and 7.3.

Table 7.1General toolbar

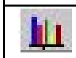
Icon	**Name**	**Action**
	Make Territories	Opens the Make Territories window, where you can choose the options or run Make Territories on all location extensions.
	Assign Days	Opens the Assign Days window, where you can choose the options or run Assign Days on all territories.
	Locate	Opens the Locate window, which you can use to find a location, driver, or equipment on a territory, week, or route.
	Territory Scoreboard	Opens the Territory Scoreboard, which shows statistical information about the territories.
	Route Summary	Opens the Route Summary, which shows statistical information about the routes.
	Unassigned	Opens the Unassigned window, which lists all location extensions not assigned to a territory.

Table 7.2 Routing toolbar

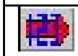
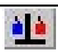
Icon	**Name**	**Action**
	Plot	Opens a map showing the selected routes.
	Route Properties	Opens the Route Attributes notebook, showing the attributes for the selected routes.
	Assign Sequential Route ID	Opens the Assign Sequential Route ID window, where you can specify the prefix and starting number that will be used for the selected routes' new IDs.
	Sequence	Sequences the selected routes based on least distance.
	Flip	Reverses the stop order on the selected routes.
	Time Window	Sequences the selected routes based on the stop's time windows and the selections made in the Options notebook.
	Line Sequence Midpoint	Sequences the selected routes based on the travel time between stops, using the stop that is furthest from the others as the starting point.
	Line Sequence Endpoint	Sequences the selected routes based on travel time between stops, using the two stops that are farthest apart as the first and last stops.
	Locate on Map	Zooms an open map to the route.
	Flash on Map	Flashes the route on an open map.

Table 7.3Territory toolbar

Icon	Name	Action
	Unrouted	Opens a list of location extensions in the territory that have not been placed on routes.
	Location Extensions	Opens a list of location extensions assigned to the territory.
	Assign Sequential Territory ID	Opens the Assign Sequential Territory ID window, where you can specify a prefix and starting number that will be used for the selected territories' new IDs.
	Balance	Balances the selected territories using the parameters last saved in the Make Territories Options notebook.

The first step to using Territory Planner is to set up and maintain the data. The Maintenance module allows you to enter all of your customer's essential information, which is then used to create your routes.

There are 10 steps you need to complete before you can begin creating your territories.

These steps are:

1.adding regions,

2.adding equipment types and equipment

3.adding employee types and employees

4.adding drivers,

5.adding scenarios,

6.adding service time types,

7.adding time window types,

8.adding service patterns and service pattern sets,

9. adding planning sessions,

10. adding location types

1.Each area or organization for which you create routes is referred to as a region; you could set up separate regions for each depot. Before you can start using the Roadnet Transportation Suite, you must add at least one region.

2.Equipment types define the types of equipment you use, such as whether you use straight trucks or trailers. You can define the dimensions of a type of equipment and specify its capacity. In addition, you can associate equipment types with locations, so that type will be used when that location is routed. After equipment types are completed, the individual pieces of equipment can be entered. Adding equipment type can be seen below Figure 7.3.

In the application two equipment type defined:Hotsell Truck and Presell Truck.

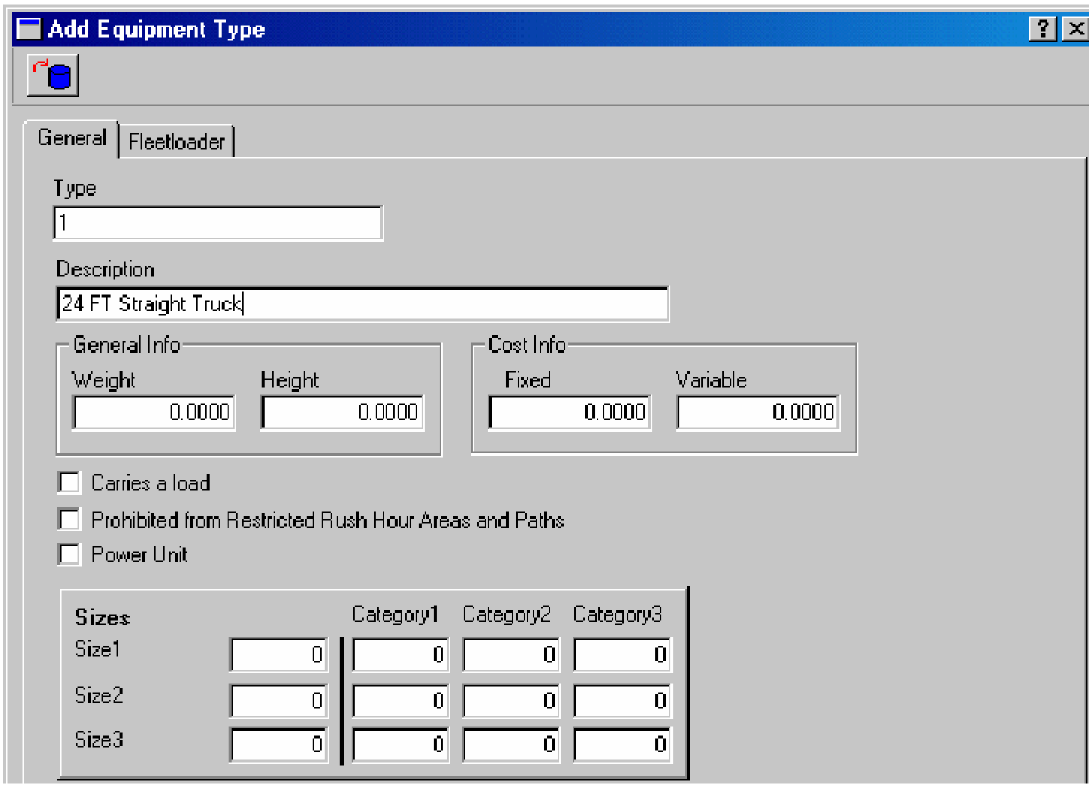


Figure 7.3 Add equipment type

3.To classify the types of employees you can use employee types. Some examples of employee types are driver, dispatcher, merchandiser, or helper. Employees can be associated with types when they are added. You can specify how much a driver is paid in many different ways, such as per hour, per stop, or per quantity delivered. This information is used when the route cost is calculated.

In application three employee type defined:

DRV:Driver

DSP:Dispatcher

SPN:Sales Person

4.Adding drivers: Drivers are those employees who are tracked through the Roadnet Transportation Suite on a daily basis. You can specify how each driver is paid; this pay information is used to help determine the total cost of a route. When adding a driver, you can also assign the equipment that driver normally uses for the Transportation Suite to track.

5. Adding Scenarios :With using scenarios you can apply changes to time windows, service times, and even service pattern sets .

The Roadnet Transportation Suite includes one default scenario, which you can use for general purposes. If you need to update the service times for a session,you can create a new scenario to instantly update the service times for every customer in that session. The scenario will be there for you to use when you need it, but the update will occur for that day’s routes only; subsequent sessions will revert to your default scenario.

6.Service time types help you group your locations by a common characteristic. Service time types allow you to specify that a group of locations has the same fixed and variable service times because the delivery environment is the same. Service time types may be, but don't have to be, correlated directly with account types.The service time types that you add can be assigned to your locations. Service time types are also created for each scenario, so an individual location may have multiple service times depending on the number of existing scenarios.

Service times are times spent delivering product to a location.

Bulk service times are times spent delivering product on pallets. The bulk service times will be used if the order is over the location's bulk threshold or if the order is forced to use bulk service times.

Fixed service time is the amount of time, independent of quantity of product delivered, that it takes to service a location. Fixed service time includes parking the truck, filling out paperwork, etc.

Variable service time is the amount of time it takes to move one unit of product from the equipment into the location receiving the delivery.

7.Time window types allow you to specify that a group of locations has the same time windows, such as a chain of fast-food restaurants. The time window types that you add can be assigned to your locations. Time window types are also created for each scenario, so an individual location may have multiple time windows depending on the number of existing scenarios. Making the time windows as wide as possible is advised. Narrow and unnecessary time windows restrict the system and make it more difficult to achieve cost savings on routes.

8.Service patterns describe the percentage of delivery on each day of the week as well as the number of weeks between deliveries. Once all service patterns have been entered, they can be grouped into service pattern sets, which are used to define location delivery options in Territory Planner. For example, a set may contain one service pattern that delivers 100% on Monday with a quantity level of 0-50 cases and another service pattern that delivers 50% on Wednesday and 50% on Friday with a quantity level of 51-100 cases.

9.Planning sessions are a way of grouping information necessary to solve routing problems in Territory Planner. They also enable you to change parameters and try different "what if" variables without losing existing routes. When you enter the Planning Editor you must select a specific session with which to work. Planning sessions can also be added by importing location extensions or choosing Transfer Session when in the Planning Editor. Adding planning sessions menu is showed in Figure 7.4.

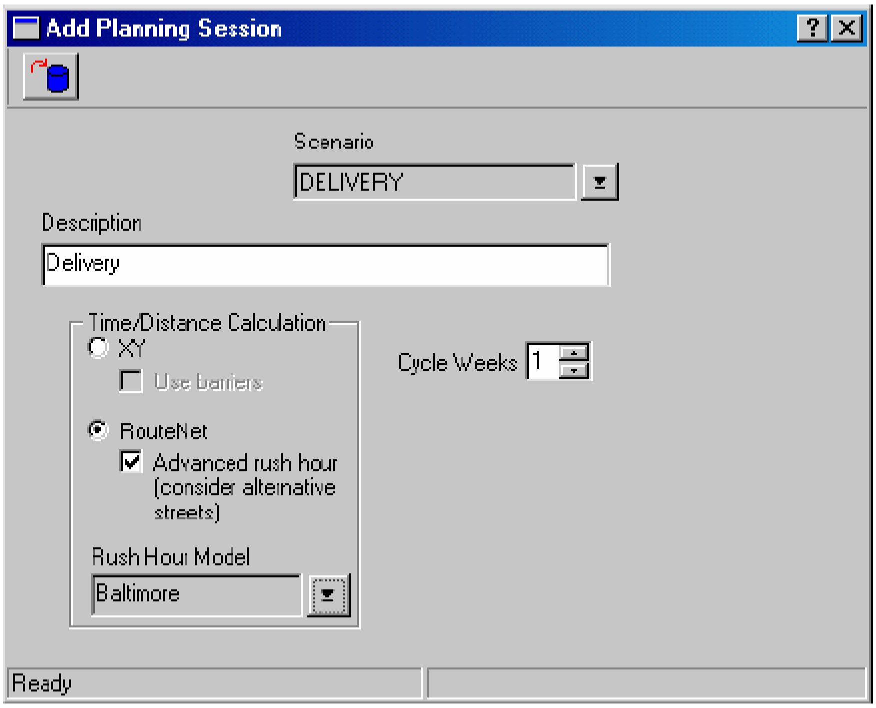


Figure 7.4 Adding planning sessions

XY is a routing method that uses a straight line to measure the distance between two points; it relies on the distance and travel time models to account for curves and turns in the road as well as varying speeds. Compared with ROUTENET, the XY method is quicker to use but less accurate.

Use Barriers can be selected only when the XY method is being used. This option accounts for actual barriers between two points, such as a body of water, a mountain, etc. Barriers must be created in the Barrier mode on the map.

Routenet is a calculation method that uses maps to replicate the actual road conditions, accounting for everything from stop signs and traffic lights to speed limits and road changes. Compared with XY, Routenet takes a little longer to process but is more accurate.

10.Location types allow you to specify the kinds of locations you have. Locations are the customers you deliver to, the depots you use, the vendors from whom you purchase product anywhere you might send a piece of equipment. The Roadnet Transportation Suite places the locations on a map according to their geocodes(latitude and longitude). You can associate many features with a location, including the address, phone, and fax number; account, time window, and service time types; and time window and service time overrides. Locations can be imported through the Import Module or added individually.

The Roadnet Transportation Suite comes with two default location types: depots (DPT) and sites (SIT), but you can add as many as needed. The menu is seen below in Figure 7.5.

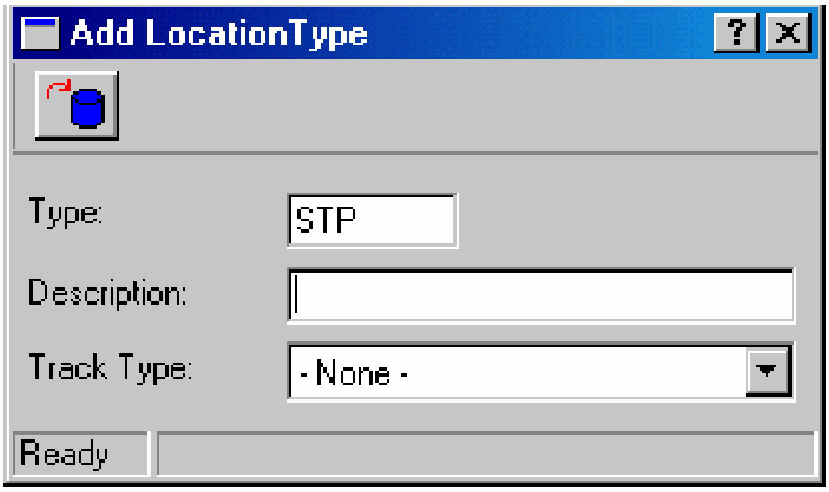


Figure 7.5 Add location type

Geocoding the Location :Geocoding is a process by which geographic coordinates (latitude and longitude) of a location are determined based on street address, zip code or other location descriptors. UPS allows you to geocode the location. The geocode assigns a latitude and longitude to the location, which is used when determining travel time for your routes. If the location does not geocode automatically, you can select databases to search to find a close match for your location, or you can move the map to find the correct geocode for the location.

7.2.1 Making Territories with Territoy Planner

To make territories first click options. Figure 7.6 showes make territories screen.

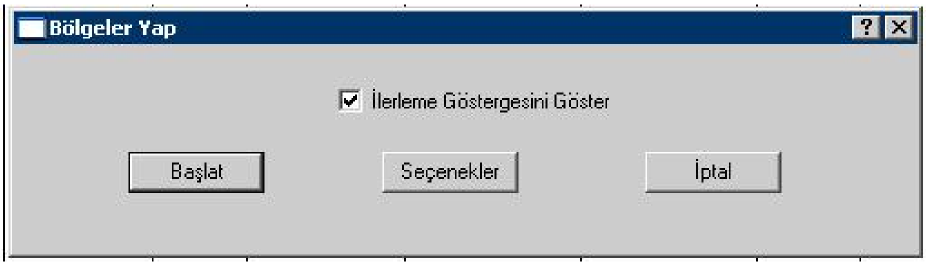


Figure 7.6 Make territories

7.2.1.1 General Options

The General Options Page of the “Make Territories” lets you specify the basic parameters that will be used when your territories are created, such as the number of territories you want to create and the shape of the territories. Each of the options on the General page is explained below.

Step1:Choose a strategy for creating the territories. The strategy you select will affect the shape of the territories that are built.

Clusters:the most common choice. The cluster strategy attempts to create territories where the locations are closely grouped together around the depot, which is near the center of the territory. If you choose this strategy you can specify the number of territories you want created and have the Planning Editor calculate the average number of stops, quantity, locations, and service time for each territory. Or, you can specify the average number of stops, quantity, locations, and service time you want in each territory and let the editor determine the number of territories that will be needed. This choice will be the most important criteria that is used when creating the territories. The cluster option also lets you choose secondary balance criteria and to optimize the territories.

Spokes (in line with depot):the spokes strategy creates territories that are oriented to each other like the spokes of a wheel, with the depot at the center of the spokes. If you choose this strategy you can specify the number of territories you want created and have the Planning Editor calculate the average number of stops, quantity, locations, and service time for each territory. Or, you can specify the average number of stops, quantity, locations, and service time you want in each territory and let the editor determine the number of territories that will be needed.

Depot Distance Only:the simplest strategy of all. The depot distance only strategy simply groups the locations in territories according to the nearest depot. If you choose this option you can not specify the number of territories you want made, any optimization parameters, or any of the options on the Advanced page.

Step 2: If you choose the cluster or spokes strategy, specify the primary criteria for creating territories. Select either Specify Number of Territories or Specify Goals.If you chose Specify Number of Territories, enter the number of territories you want created; the Planning Editor calculates the average number of stops, locations, quantity, and service time for each territory.

If you chose Specify Goals, select the parameter you want to set the goal for and enter the average you want in each territory; the Planning Editor will calculate the number of territories needed to meet that goal.

Figure 7.7 showes make territories general options screen.

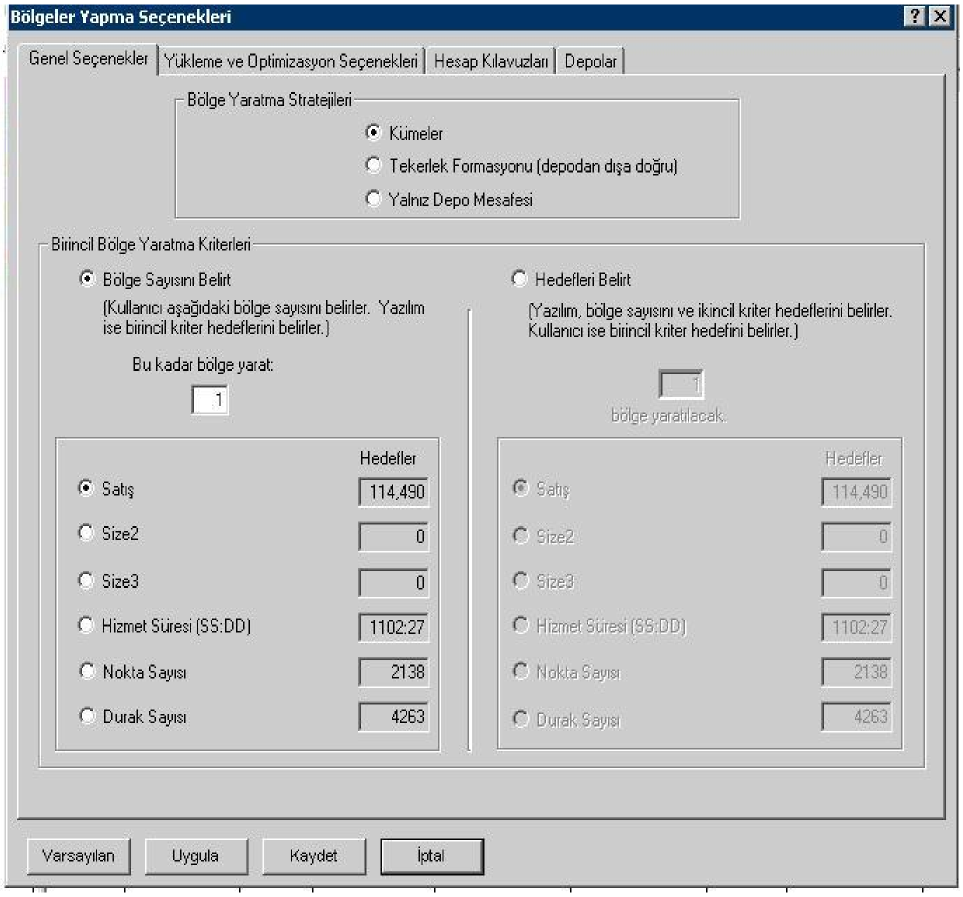


Figure 7.7General options of make territories

7.2.1.2 Optimization Page

The Optimizations page of the Make Territories lets you specify the secondary criteria that is used when creating and optimizing the territories, as well as place some limits on the optimization process. These options are only available if the Cluster strategy was selected.

Step 1: Move the slider bars to indicate the relative importance of balancing the territories on that factor. The options are the same as on the General page, where you selected the primary balance criteria, with the addition of balanced run time. The Balanced Run Times slider works a little differently than the other slider bars. If the slider is maximized (High), the effort to create territories with balanced run times is greater than the effort to balance territories on the criteria selected on the General page. If the slider bar is minimized (Low), no effort will be made to create territories with balanced run time.

Step 2: If you want to optimize the territories, check Enable Optimizations and choose when the optimization process should stop. You can specify the number of iterations the optimization should include, or you can let the software decided when no improvements can be made.
Figure 7.8 showes optimization page of make territories.

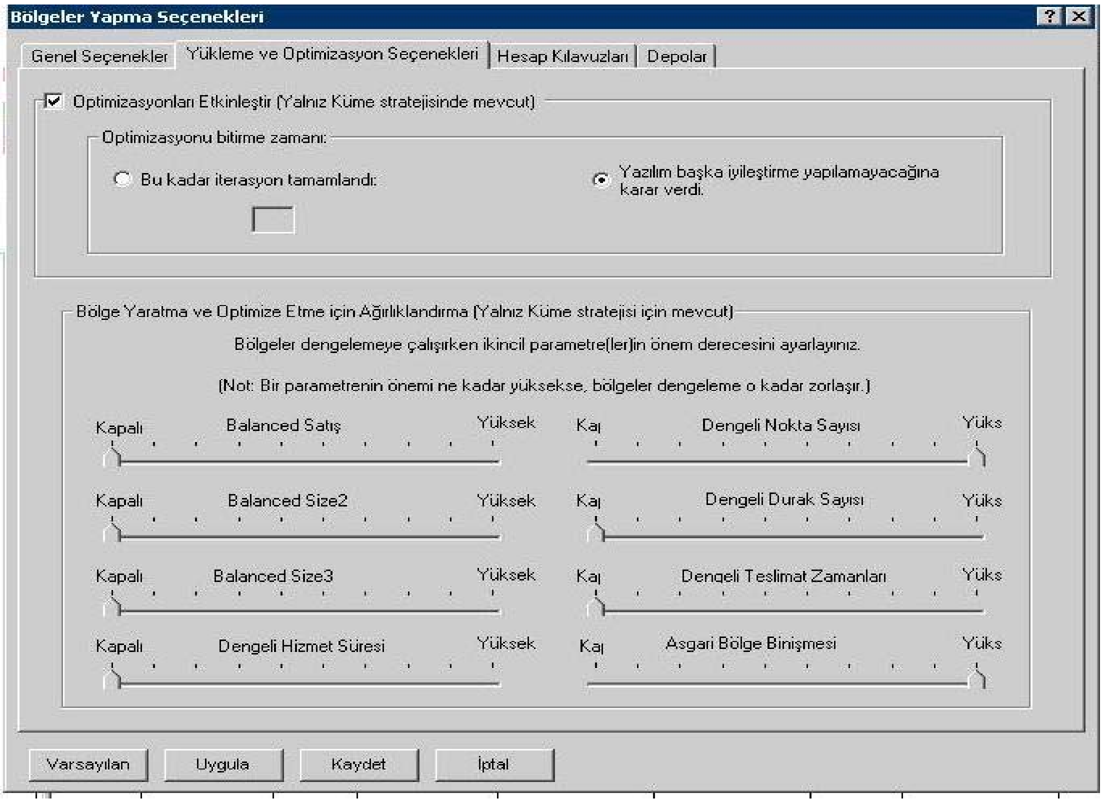


Figure 7.8 *Optimization Page*

7.2.1.3 Account Guidelines Page

The Account Guidelines page of the "Make Territories" lets you specify which account types must be included in every territory, and how many must be in each territory. For instance, your business may require that each territory contain at least one large grocery store. You could simply set up a grocery account type, assign it to the appropriate locations, and then specify here that each territory must contain at least one grocery store. The account guidelines are only available if the Cluster strategy was selected on the General page.

Step 1: Check the Enable Guidelines box and select the account types that must be included in every territory from the list below.

Step 2: Choose whether to specify that each territory must contain a certain number of that type (Number of each type desired per territory) or whether the number in each territory is based on the primary criteria (Use whatever number corresponds to this percent of a territory’s primary criteria).

Figure 7.9 showes account guidelines page of make territories.

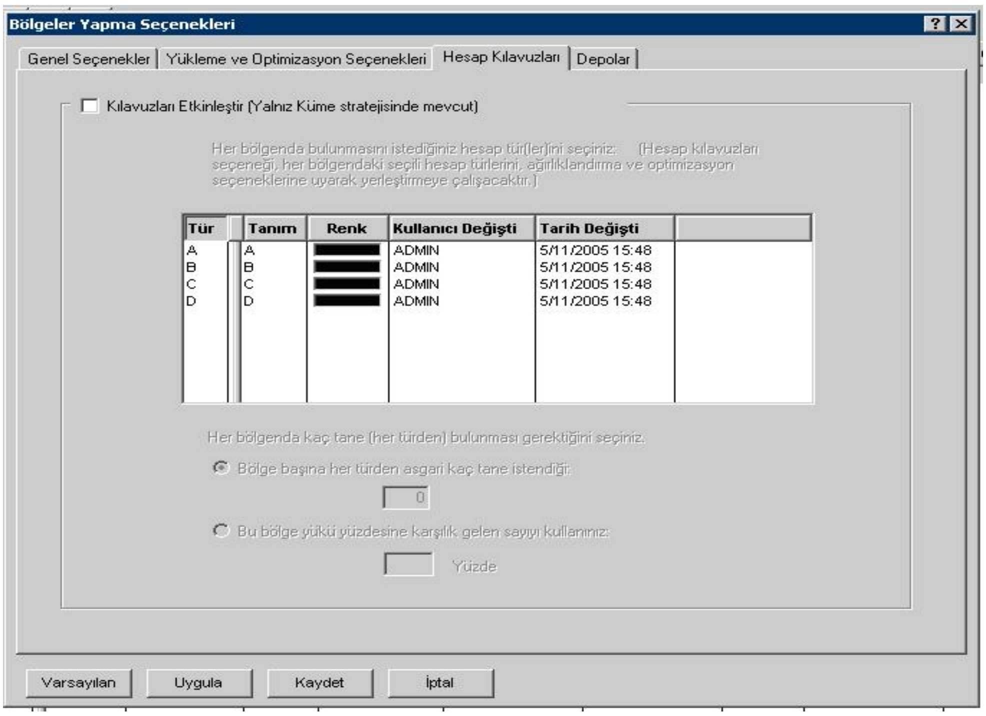


Figure 7.9 Account Guidelines Page

7.2.1.4 Depots Page

The Depots page of the Make Territories lets you indicate which depots are active, and the number of pieces of equipment that are available at the depot. When territories are created only depots that are assigned resources will be given territories, but all depots with resources will be considered. So, if you do not want a depot to be used, make sure it has no resources assigned to it.

Figure 7.10 is the depots page of the make territories options.

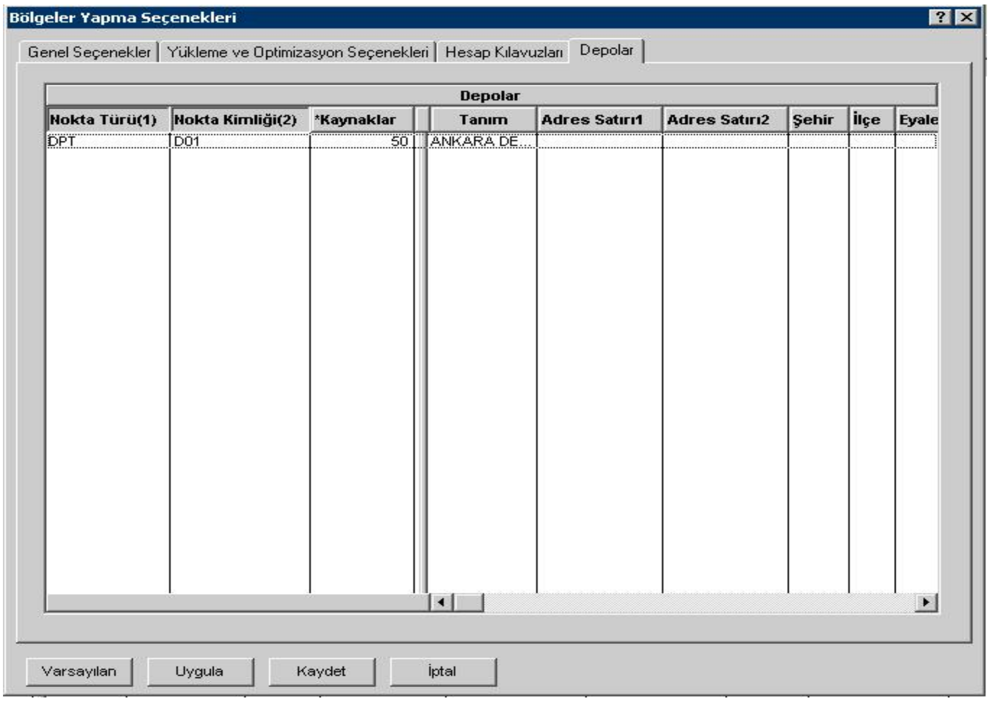


Figure 7.10 Depots page

After applying Make territories Options click start button. Then territory Planner begins to optimize territories according to your choises.

The optimization screen can be seen in Figure 7.11.

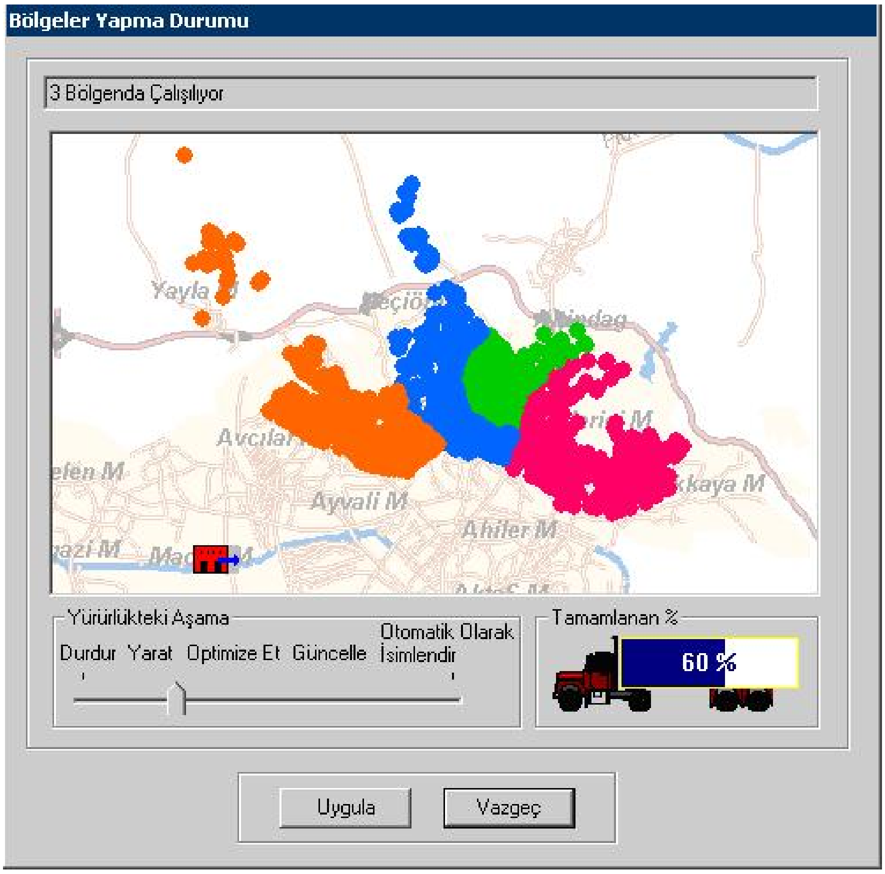


Figure 7.11 Optimization screen

After all this steps territories are created in the Planning Editor. However, the locations that are assigned to the territory have not been placed on routes. You can route the locations manually, or use Assign Days to place the locations on routes.

7.2.2 Assigning Days with Territory Planner

The assign days screen can be seen in Figure 7.12.

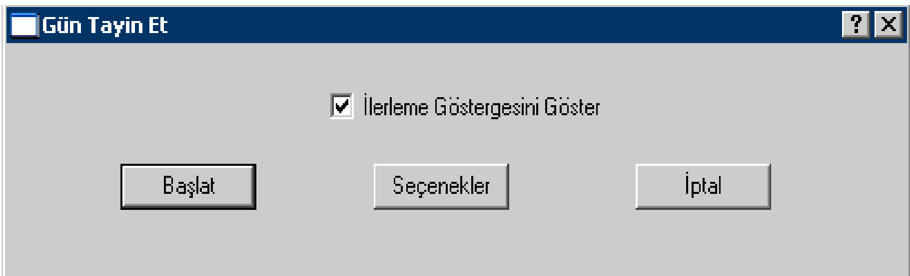


Figure 7.12 Assign days screen

7.2.2.1 Score Parameters Page

The Score Parameters page of the “Assign Days” lets you specify the factor(s) that should be considered when the routes are created, and how heavily each factor should be considered. The choices are Importance of Balanced Run Length, Importance of Balanced Load, and Importance of Cost. Slide the bars to indicate the relative importance of each option to the other options.The position of the slider bars is relative, therefore sliding all the bars to the High position is the same as leaving all of them in the Low position.

Importance of Balanced Run Length indicates the importance of the routes within each territory having similar run times.

Importance of Balanced Load indicates the importance of the routes within each territory having similar quantities. The size alias used for balancing is determined by the Primary Balance Size setting on the Load Parameters page.

Importance of Cost indicates the importance of running the lowest possible cost route.

The route cost is calculated using the costs assigned to the drivers and equipment.

Figure 7.13 shows score parameters page.

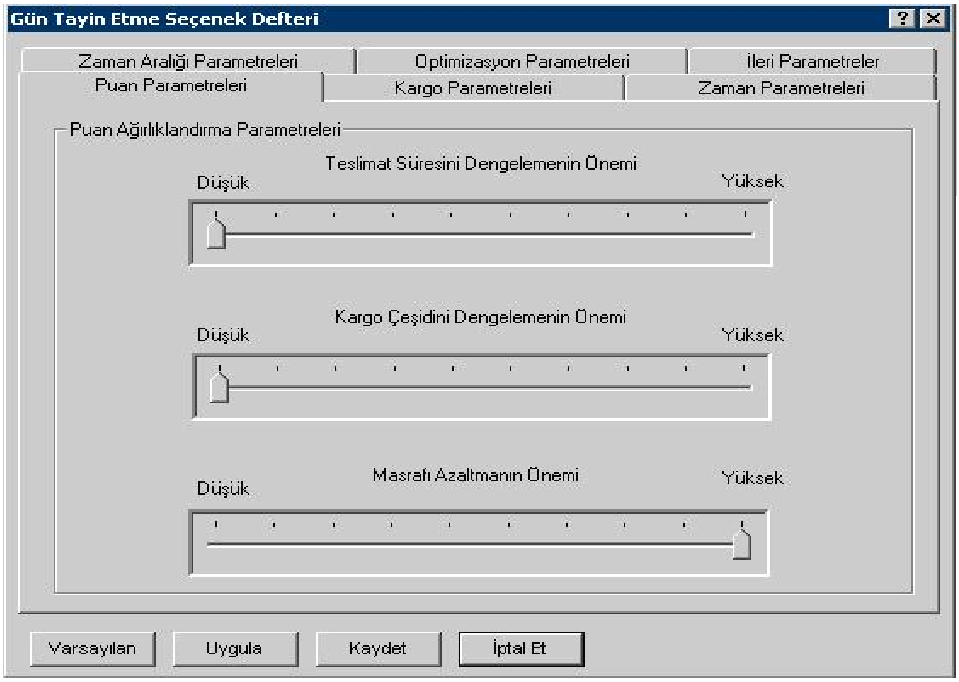


Figure 7.13 Score parameters page

7.2.2.2 Load Parameters Page

The Load Parameters page of the Assign Days Options lets you establish how you want the load balanced throughout the week, select the size to use for balancing load, and enable capacity restrictions.

To balance the load other than evenly throughout your delivery week**,** check the Enable box in the Daily Load Distribution Goal Percentages area. Enter the percentage of the load you want delivered on each day; the total must equal 100 percent. If Importance of Balanced Load is set on the Score Parameters page, it will use these percentages when “balancing” the routes. If there is a day when you do not want any product to be delivered, you can use this feature and set that day’s percentage to 0.

To choose the size that will be used to balance the load, click on the appropriate choice in the Primary Balance Size area.

To keep routes with more than a specified quantity from being built, check the size in the Route Capacity Restrictions area and enter the maximum quantity the route can contain for that size. If you would rather simply use the equipment's capacity, check Use Equipment Capacity. Any stops that cause a route to exceed its capacity restriction will be unassigned and not placed on another route.

Figure 7.14 shows load parameters page.

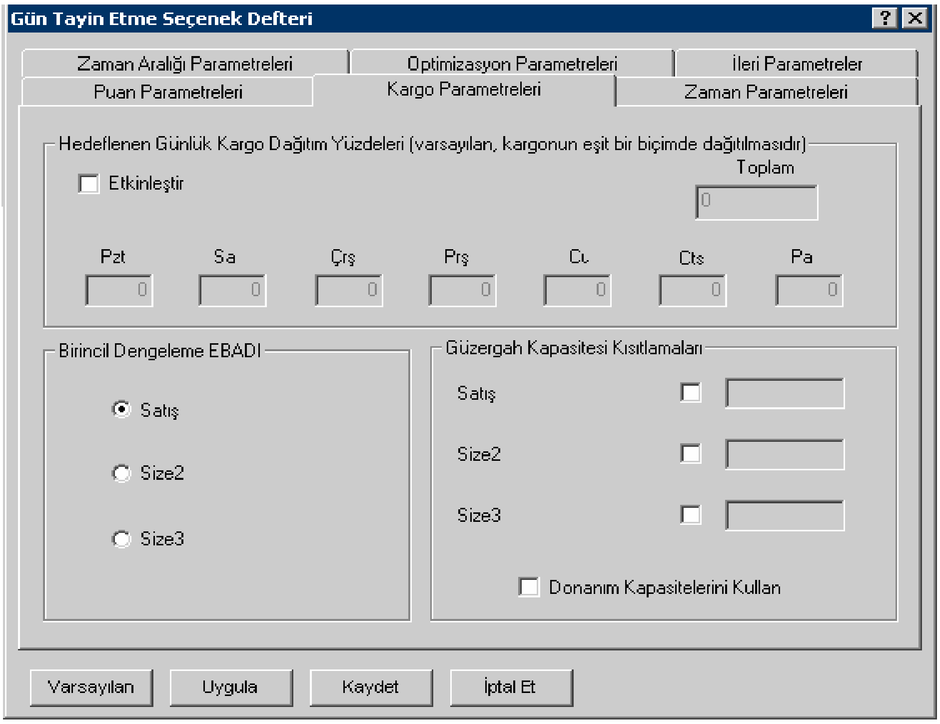


Figure 7.14 Load parameters page

7.2.2.3 Time Parameters Page

The Time Parameter page of the "Assign Days" lets you specify several route factors dealing with time, including the daily start times, and preferred and maximum run lengths for each day of the week.

To establish route start times on a daily basis, enter the desired start time for the day in the Start Time Override fields. These start times are overrides, and, where specified, will be used instead of the start time entered on the Routing page of the Options.

To create preferred run times on a daily basis, enter the desired run time for the day in the Preferred Run Length fields. If you enter a preferred run length on one or more days, days without a specified run length will not be routed.

This feature can be used to create uneven routes throughout the week. For instance, if you wanted to create shorter routes on Friday, you could give Friday a shorter preferred run length than the remaining days of the week.

To specify a maximum run length on a daily basis, enter the maximum run length in the Maximum Run Length fields. Any stops(customers) that cause a route to exceed its maximum run length will be unassigned and will not be placed on other routes.

Figure 7.15 shows time parameters page.

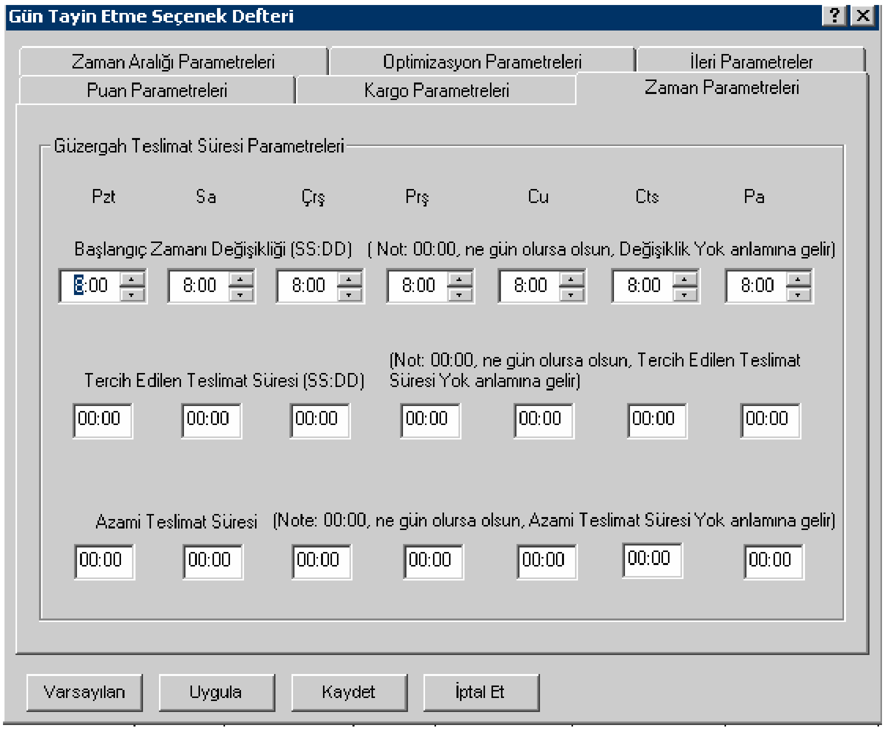


Figure 7.15 Time Parameters Page

7.2.2.4 Time Windows Page

The Time Windows page of the “Assign Days” lets you enable time window processing of the routes. If time window processing is enabled, the routes are sequenced according to the stops’ time windows after the routes have been created.To allow the routes to be resequenced by time windows, check Enable Time Window Processing.To allow the routes’ start times to be adjusted to meet more stops’ windows, check Adjust Start Times and enter the earliest and latest the start times can be moved to, and the number of minutes to move start times in (15 minutes increments, 30 minute increments, etc.).

Figure 7.16 shows time windows page.

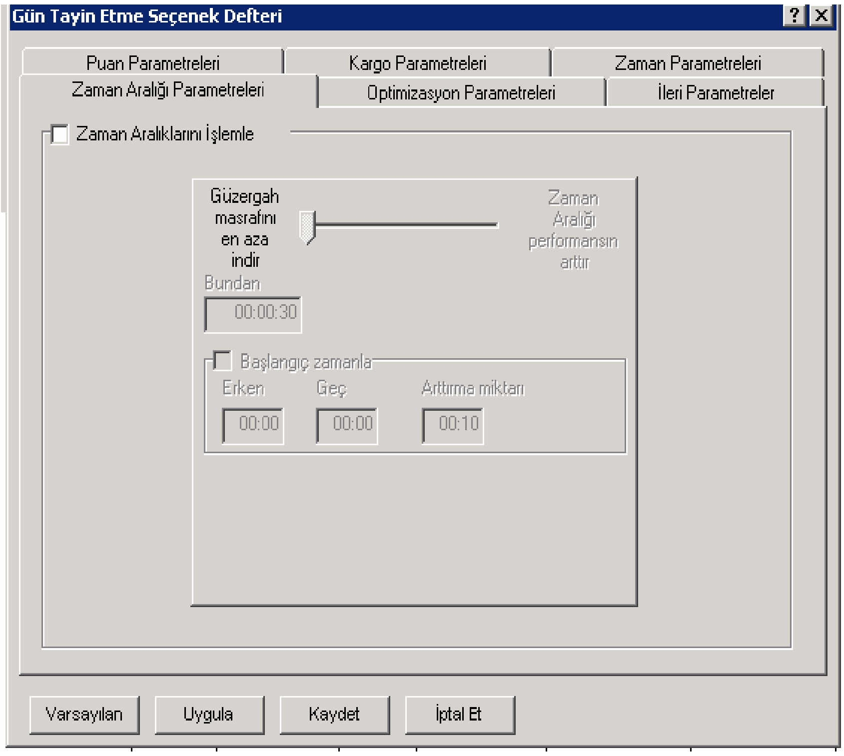


Figure 7.16 Time Windows Page

7.2.2.5 Optimization Parameters Page

The Optimizations Parameters page of the Assign Days lets you define the rules that will be used to optimize the routes. The optimization process occurs after the initial routes have been created, and involves moving stops from one route to another to see if the answer is improved.

To limit the length of the optimization process, select one of the choices in the Optimization Completion Criteria area. You can choose to have the process end when a specified amount of time has passed, or when the variance between the largest and smallest load and/or run length has reached a defined level. Using these options may cause Assign Days to stop working before the best solution has been found.

To indicate how hard the optimization process should work**,** move the Optimization Effort Level slider at the bottom of the page. The higher the optimization level, the longer the optimization process will take.

Figure 7.17 shows optimization parameters page.

7.2.2.6 Advanced Parameters Page

The Advanced Parameters page of the Assign Days Options lets you tweak the rules used for the optimization process plus specify some advanced features for how the routes are created. The options on this page should not be used until you are fine tuning your routes. Each option is discussed below.

Use the following options to tweak the optimization process:

Number of Optimization Passes—specifies the number of routes to optimize. A pass is considered complete when one route has been optimized.

Number of Moves to Look Ahead—defines how hard Assign Days should analyze the results of every move made during the optimization process. Increasing the number of moves to look ahead can quickly and dramatically increase the amount of time needed to optimize the routes. This number should not be set higher than 3.

Quit Recursion when First Better Move Found—check to allow Assign Days to stop the optimization process as soon as a better move is found, even if not all possible moves have been tried. If this option is checked, the best route may not be created.

Number of Grid Squares Along a Side—defines the size of the area the optimization process can use to move stops to other routes. There are three entryfields here. The optimization process starts with the Large Count, and if it can not find a satisfactory answer within grid squares that size moves to the Medium Count, and finally to the Small Count.

Use the following options to provide additional guidelines for the initial route creation process:

Cluster Duplicate Latitude / Longitudes—groups locations with identical latitude and longitude, service pattern sets, and delivery quantity. The degree to which the latitude and longitude must match is set using Precision Factor. The number entered in the Precision Factor field indicates the number of digits to remove from the end of the latitudes and longitudes before looking to see if they are identical.

Method for Laying out the Regions for the Routes—you can choose to have your routes created based on clusters or spokes. These options are similar to the cluster and spoke options in Make Territories, and refer to the shape of the routes that will be created.

Figure 7.18 showes advanced parameters page.

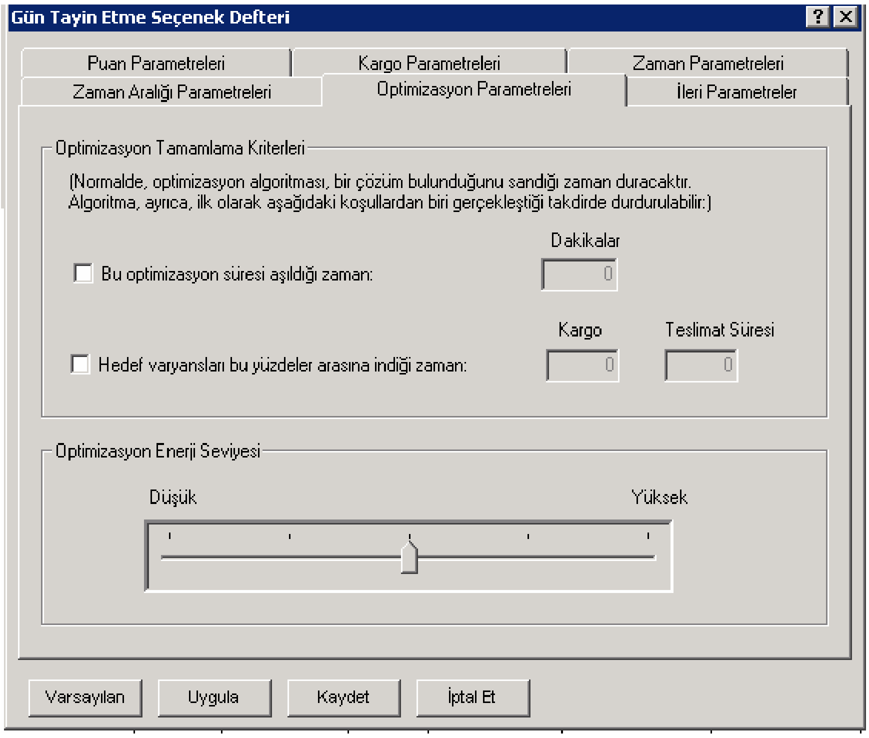


Figure 7.17 Optimization Parameters Page

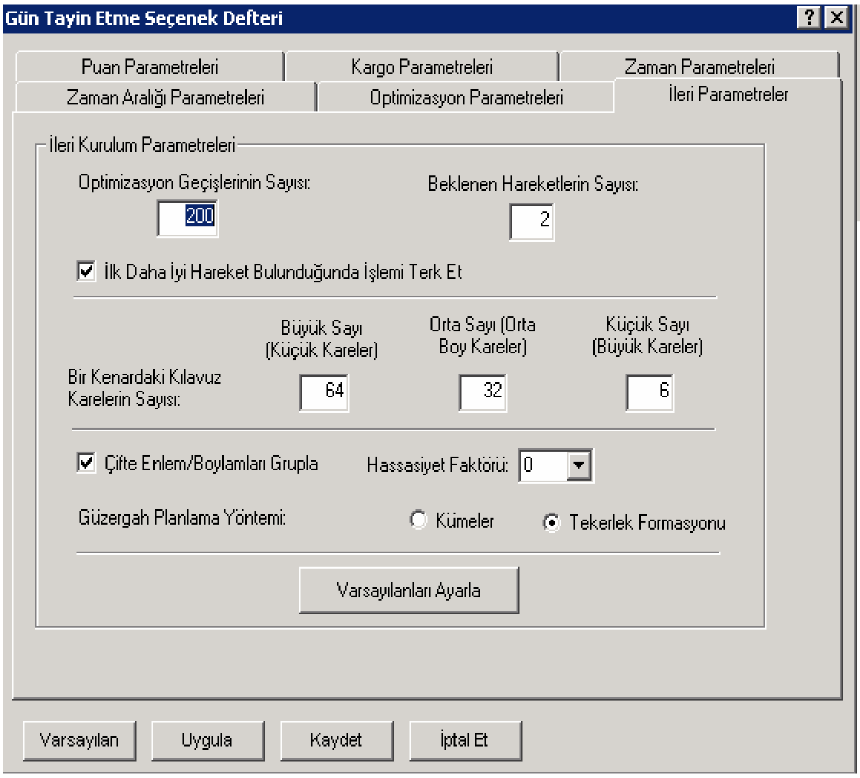


Figure 7.18 Advanced Parameters Page

7.3 Heuristic Approach Behind the Territory Planner

Territory Planner is used a cluster first, route-second heuristic. The heuristic approach is constructed in two stages: (1) the assignment procedure, and (2) the sequence procedure.

7.3.1 Assignment Procedure

The assignment procedure consists of two major step:
1.creating an initial solution (an initial clustering of customer locations),
2. improving the initial solution.

7.3.1.1 Creating an Initial Solution

To build an initial solution, the algorithm considers only a customer's geographic location (latitude and longitude) and creates territories according to user's choice(clusters, spokes or depot distance only) Each territory represents the set of locations assigned to one vehicle. However, during this step, the algorithm does not consider such factors as real travel time (distance traveled) and service time or visit time window for each customer.

7.3.1.2 Improving the Initial Solution

Because the algorithm considers only geographic locations of customers in the first step, the assignments may not be realistic. Some vehicles may be assigned longer service times than others, and workloads may not balance. To correct such problems, the algorithm executes an improving process for assignment. At this step, the algorithm iteratively transfers customers from one territory to another or exchanges customers between territories. By means of these transfers or exchanges, the algorithm attempts to balance the predefined parameters such as the balanced run times,balanced number of customers or balanced service times . During each transfer or exchange, the algorithm finds the operation that generates the best benefit (that is, a better balanced route, minimized overlap, and minimal service time or distance).

The algorithm finishes this step according to customers predefined choice (the following number of iterations have completed or the software decides that no additional improvements are possible)

7.3.2 Sequence Procedure

The sequence procedure determines the daily routes for all vehicles over the entire planning period and simultaneously finds the optimal visiting sequence for each customer within each daily route.

When it has finished the sequencing procedure, the algorithm creates a daily route for each vehicle for each day of the planning period.

The sequence procedure considers the following factors while building the daily routes for a vehicle:

Balancing Requirements (load ,route lenght,..)

The frequency of visits to a location,

The service time per visit for each customer type

The time window the customer imposes

The salesman’s working hours per day.

Start Times/Run Times

The sequencing algorithm arranges the visiting day(s) for customers and the sequence of visits within a salesman’s daily route. Furthermore, the management can use the sequencing algorithm to reschedule daily routes, for instance, after inserting new contracts for a customer.

The sequence procedure performs two major tasks: (1) assigning visit day(s) to each customer, and (2) sequencing the resulting daily routes, while minimizing driving time.The first step in the sequence procedure is to determine for each customer the specific visiting day(s) over the planning period. The second step is to sequence the visits within daily routes to improve the objective function further.

7.4 Benefits of Using a Vehicle Routing Software

- Decreased transportation costs
- Increased customer satisfaction
- Enhanced strategic planning capabilities
- Instant access to accurate delivery costs
- Improved resource utilization
- Enhanced driver management
- Reduced driver turnover
- Increased profitability
- What-if analysis
- Improve customer service
- Balanced capacities & workloads
- Fewer Trucks
- Reduced kilometers
- Turn-by-Turn directions
- Route Summaries (day, week and cycle)
- Visualise the whole process

CHAPTER EIGHT
APPLICATION

8.1 History of Frito Lay

PepsiCo was founded in 1965 through the merger of Pepsi-Cola and Frito Lay. PepsiCo is a world leader in convenient foods and beverages, with 2004 revenues of more than $29 billion and 153,000 employees. The company consists of Frito Lay North America, PepsiCo Beverages North America, PepsiCo International and Quaker Foods North America. PepsiCo brands are available in nearly 200 countries and territories and generate sales at the retail level of about $78 billion.

PepsiCo's snack food operations had their start in 1932 when two separate events took place. In San Antonio, Texas, Elmer Doolin bought the recipe for an unknown food product – a corn chip – and started an entirely new industry. The product was Fritos brand corn chips, and his firm became the Frito Company.

That same year in Nashville, Tennessee, Herman W. Lay started a business distributing potato chips. Mr. Lay later bought the company that supplied him with product and changed its name to H.W. Lay Company. The Frito Company and H.W. Lay Company merged in 1961 to become Frito Lay, Inc.

Frito Lay is a company which is a member of FMCG industry.

Frito Lay Turkey was founded in 1993 which is headquartered in İstanbul. It operates a plant and has a large sales-distribution network which covers whole country. The production plant is located in Kocaeli-Suadiye. Frito-Lay produces potato and corn chips such as Lays, Ruffles, Doritos, Çerezza, Cheetos. Frito-Lay also distributes sweet snacks such as Snickers, Rocco and Haribo in Turkey.The all brands are available in stores nationwide.

Frito Lay Turkey has three Distribution Center (DC) in İstanbul. They are located in Seyrantepe, Dudullu and İkitelli.

Figure 8.1 shows the brief supply chain of Frito Lay. The scope of the application is distribution from distribution centers to groceries, markets, etc.

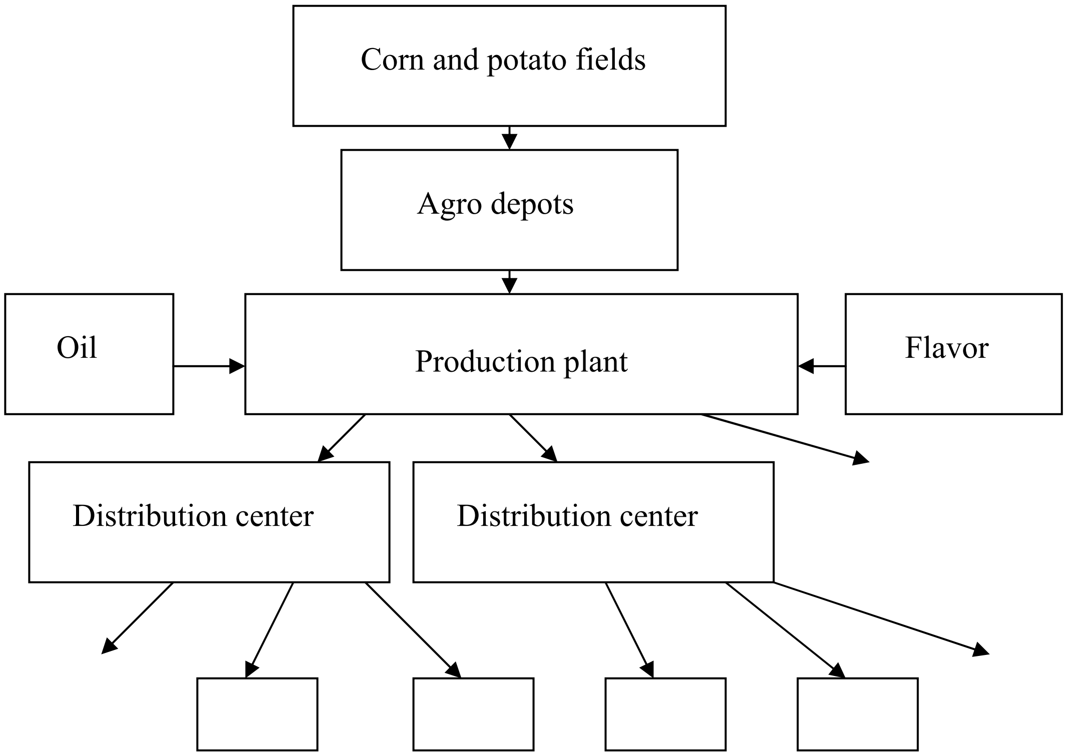


Figure 8.1 The brief supply chain of Frito Lay

Routing vehicles and making territories are a hard work to handle. Routing vehicles by optimally is needed scientific study and expert opinion together. Manuel routing methods are prone to error and time consuming. (Koçtaş & Çakmakçı, 2005)

The company's customers are currently partitioned into geographical territories, and each territory is assigned to a given vehicle. Generally territories overlap in the course of time. There is lots of reason that causes overlapping. Sometimes new customers may be insert in a wrong territory or disagreement between company's salesperson and a customer is caused inserting the customer in an another territory. Without computer support, minor route revisions gradually result in routes that overlap geographically. Overlapping increases fuel cost and salesperson's drive time.

The company has contract with distributors which paid fuel and employee cost. The company decided to launch a pilot project with the objective being min 8% reduction of the fuel cost, with using a computerized vehicle routing application. Frito Lay North America and PepsiCo Beverages North America have implemented Roadnet Transportation Suite.Frito Lay Turkey has decided to use the same software in its operations.

The pilot project focused on three distribution centers in İstanbul.

Four restrictions were imposed on the pilot project:

(1) The software should plan visits to clients according to their predefined visit frequency.

(2) The software should be flexible enough to review routes if a customer calls and requires a change in his visiting days.

(3) Customers would be grouped by territories which ought to satisfy some equilibrium conditions.(endorsement, route duration, quantity of customers)

(4) The number of customers visited per day, in each territory should be as large as possible.

About point 3: drivers are also salesmen who receive commissions**.** Therefore, since the sales potential of each customer is different, the zoning policy might be subject to disputes among drivers aiming for higher commissions.

The results can be seen below Table 8.1.

Table 8.1

	Seyrantepe DC	Dudullu DC	İkitelli DC
Reduction of the fuel cost	11%	15%	13%

This results was to be achieved by a more rational allocation of customers to vehicles and an improved sequencing of visits**.** After the succsessful implementation in İstanbul, Frito Lay decided to launch Roadnet Territory Planner in Ankara and İzmir.

8.2 Territory Planner Implementation In Ankara

Ankara DC is located in Macunköy and has approximately 8000 customers. Frito Lay has conctracted with a new distributor and decided to give a territory to the new distributor from taking a part in existing territory. It is decided that the new distributor will have a territory which includes 10 vehicles. First an area which includes 3643 customer selected. Contiguity of territories and some special factors related to other distributors effect selection criteria of 3643 customers. 17 vehicles serve to this area. To design the new distributor’s territory and optimize its routes Frito Lay decided to use Territory Planner.

8.2.1 Methodology

The objective of the project was to find the best zoning of the customers which would not only minimize the total distance travelled by the fleet, but also require the sales volume per route to be balanced. The following characteristics of the problem were considered:

Customers should be fully satisfied and all planned visits should be made at the specified frequency.

The total number of customers along a given route should be compatible with the working day of the driver.

To optimize and design territories by using Territory Planner;

1.Geocode all customers(it is a very time consuming work,it is recommended that outsource this step from a third party)
You need to have address,firm title,tax number of each customer

2.Collect data
The data collected included the following information:
Capacity of the fleet;
Average demand of each customer,
Constraints of delivery time for each customer;
Departure time of each vehicle from the depot;
Service time for each customer type;
The total distance travelled.

3.Import data into the software

4.Define your making territory strategies and apply them by means of Territory Planner.

17 territories is showed with different number and color. (Identity of territories: 100, 101, 107, 108, 2062, 215, 2484, 73, 76, 79, 81, 83, 84, 85, 86, 87, 96). Each territory is served by a vehicle, so 17 vehicles serve this area. The map of territories can be seen Figure 8.1.

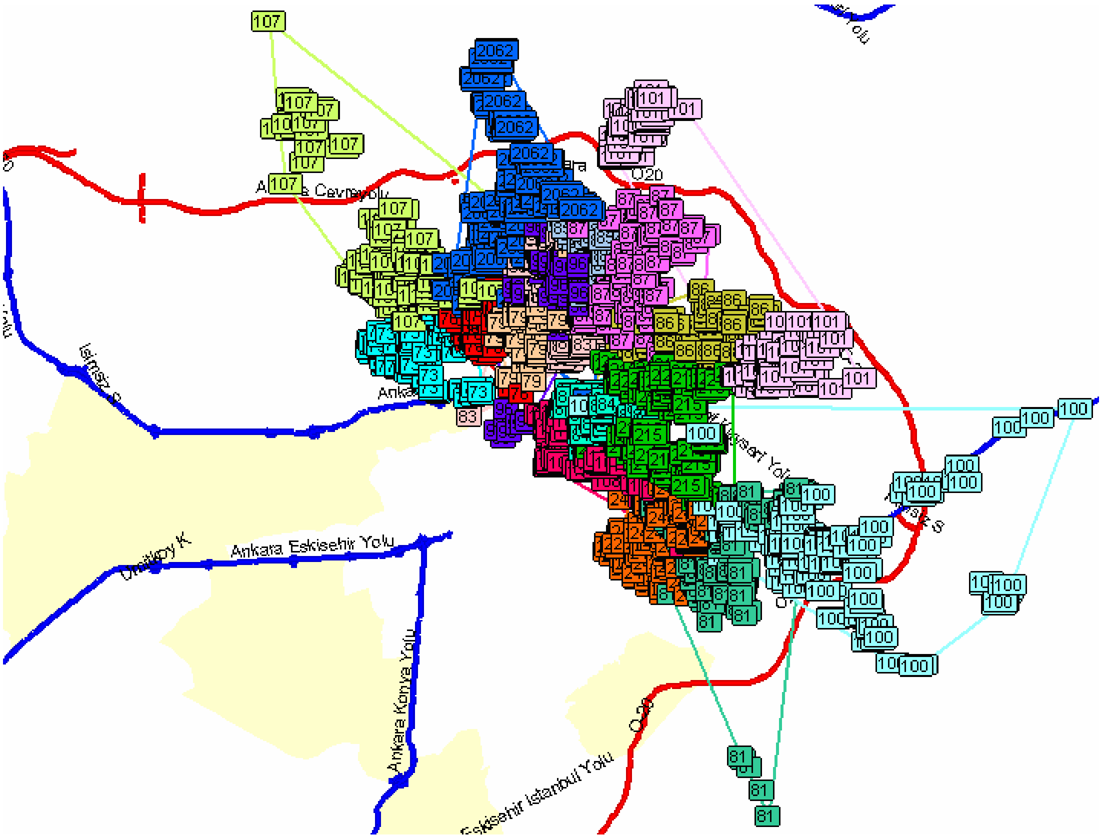


Figure 8.1 Map of 17 territories

8.2.2 Steps of Selecting The New Distributor's Territory

1.Optimize the all 17 territories by using Territory Planner.

2.Select 10 territory.

3.Reoptimize the selected area.

3.Fine tune manually the selected area by using Territory Planner.

Current situation can be seen in Figure 8.2. There is a customer who is not assigned to any territory. (4.column)

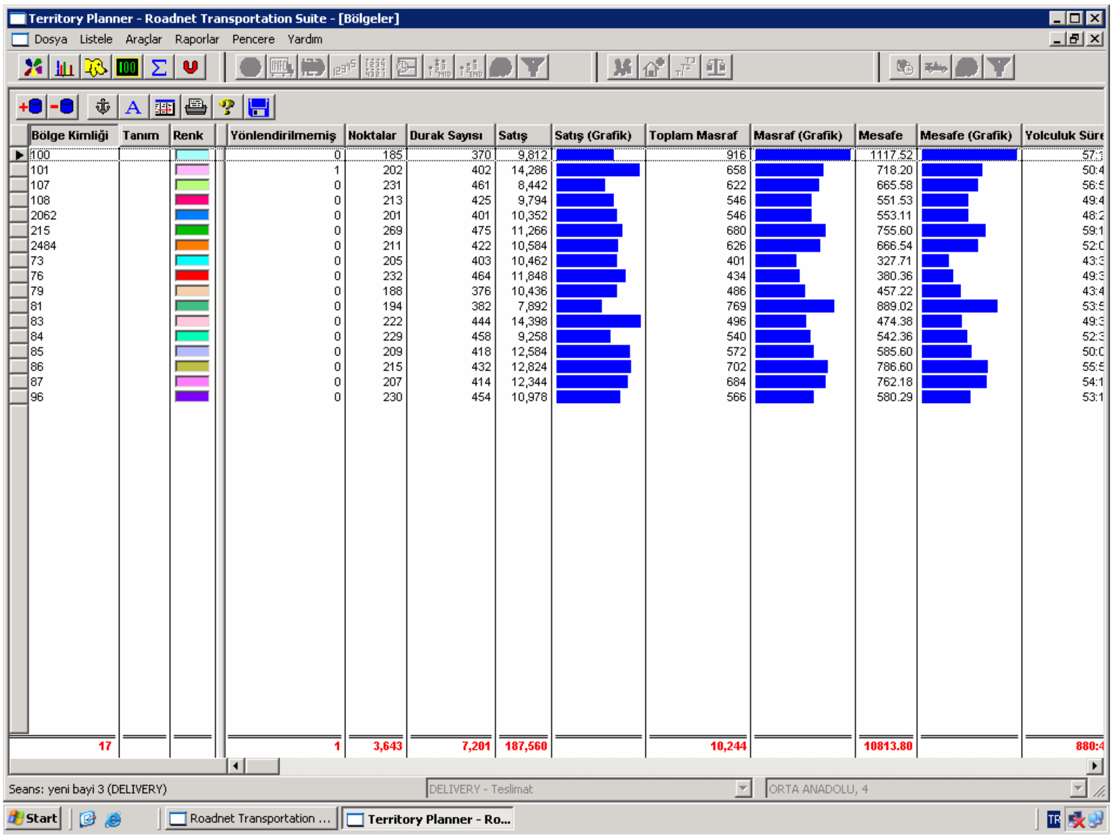
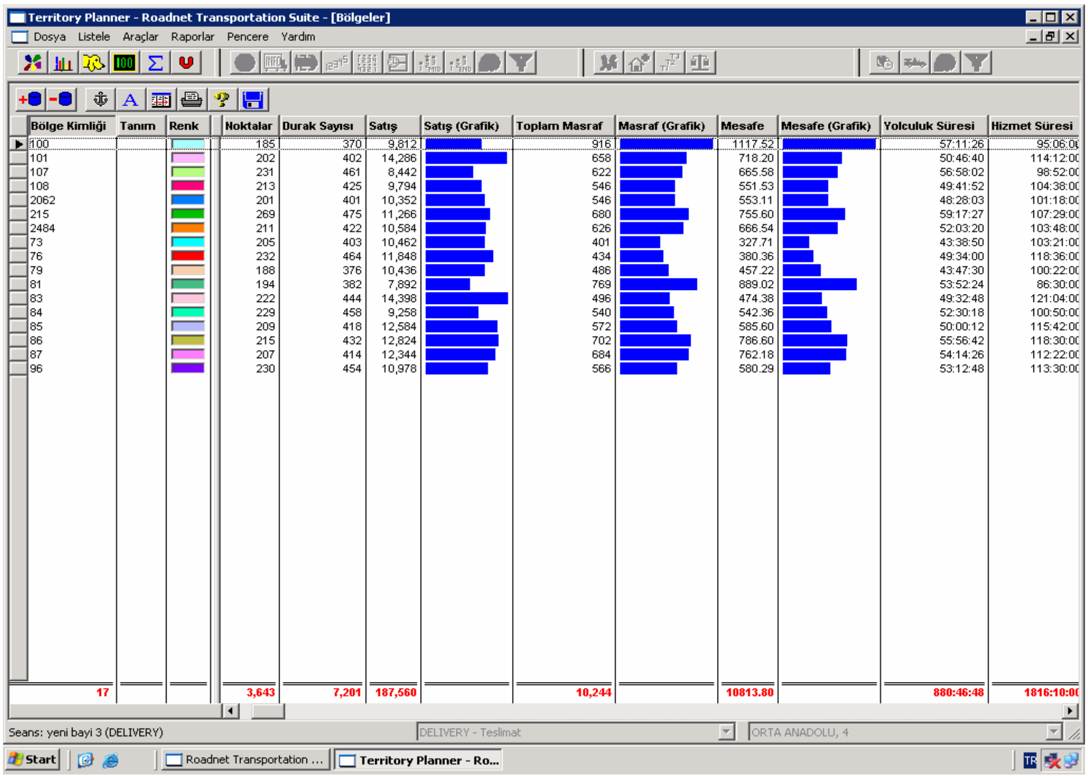


Figure 8.2 Current territories_1

To see other columns it is enough moving slider bar to the right. Figure 8.3 shows this situation.



Bölge Kimliği	Tanım	Renk	Noktalar	Durak Sayısı	Satış	Satış (Grafik)	Toplam Masraf	Masraf (Grafik)	Mesafe	Mesafe (Grafik)	Yolculuk Süresi	Hizmet Süresi
100			185	370	9,812		916		1117.52		57:11:26	95:06:00
101			202	402	14,286		658		718.20		50:46:40	114:12:00
107			231	461	8,442		622		665.58		56:58:02	98:52:00
108			213	425	9,794		546		551.53		49:41:52	104:38:00
2062			201	401	10,352		546		553.11		48:28:03	101:18:00
215			269	475	11,266		680		755.60		59:17:27	107:29:00
2484			211	422	10,584		626		666.54		52:03:20	103:48:00
73			205	403	10,462		401		327.71		43:38:50	103:21:00
76			232	464	11,848		434		380.36		49:34:00	118:36:00
79			188	376	10,436		486		457.22		43:47:30	100:22:00
81			194	382	7,892		769		889.02		53:52:24	86:30:00
83			222	444	14,398		496		474.38		49:32:48	121:04:00
84			229	458	9,258		540		542.36		52:30:18	100:50:00
85			209	418	12,584		572		585.60		50:00:12	115:42:00
86			215	432	12,824		702		786.60		55:56:42	118:30:00
87			207	414	12,344		684		762.18		54:14:26	112:22:00
96			230	454	10,978		566		580.29		53:12:48	113:30:00
17			3,643	7,201	187,560		10,244		10813.80		880:46:48	1816:10:00

Figure 8.3 Current territories_2

Table 8.2 summarizes the Figure 8.3

Table 8.2 Summary of the Figure 8.3

Number of Territory	**17**
Total number of customers	3643
Total Cost(YTL)	10244
Total distance(km)	10813.80
Service time(h)	1816:10:00
Travel time(h)	880:46:48

Figure 8.4 shows the score board of the current territory.

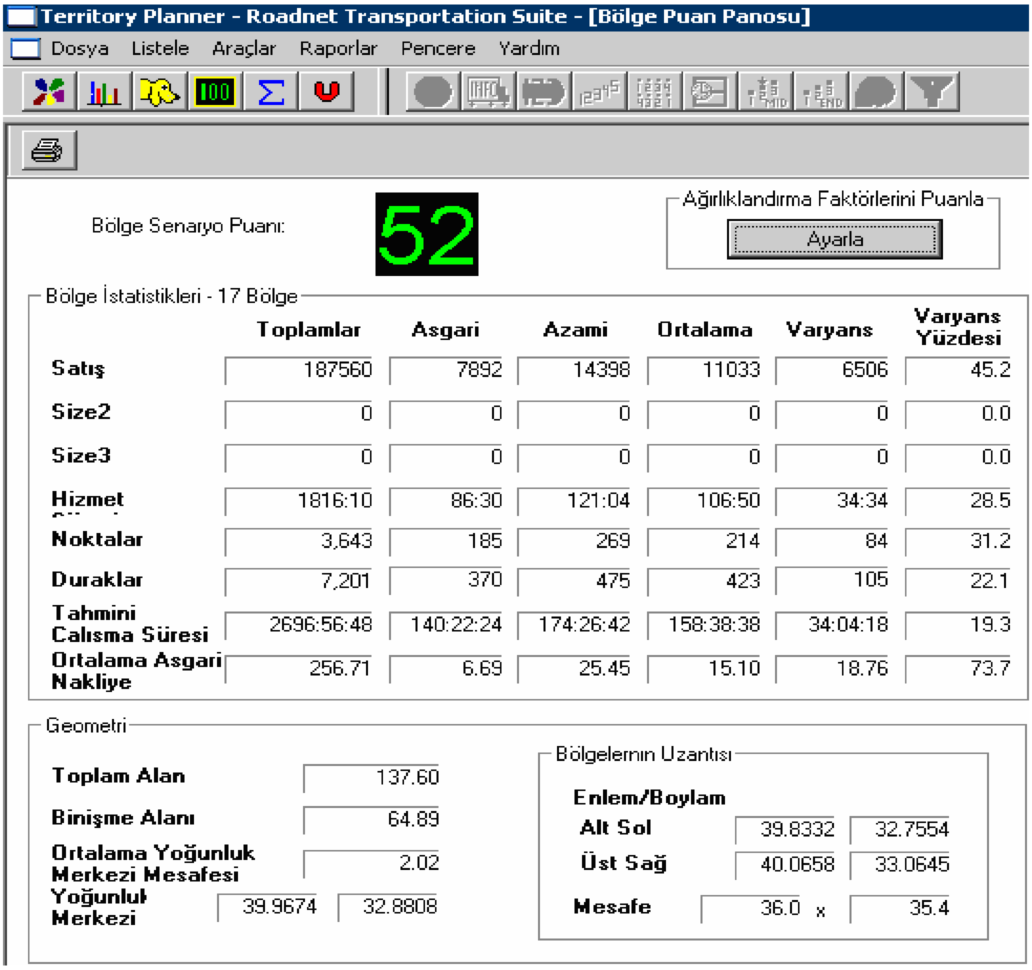


Figure 8.4 The territory scoreboard

The Territory Scoreboard shows a score for all territories based on the primary and secondary criteria selected in the Make Territories Options.

Overlapping territories cause to increase total cost and travel time.
According to above figure : Overlap area / total area:47 %

Figure 8.5 is related with overlapping map of Frito Lay's territories.

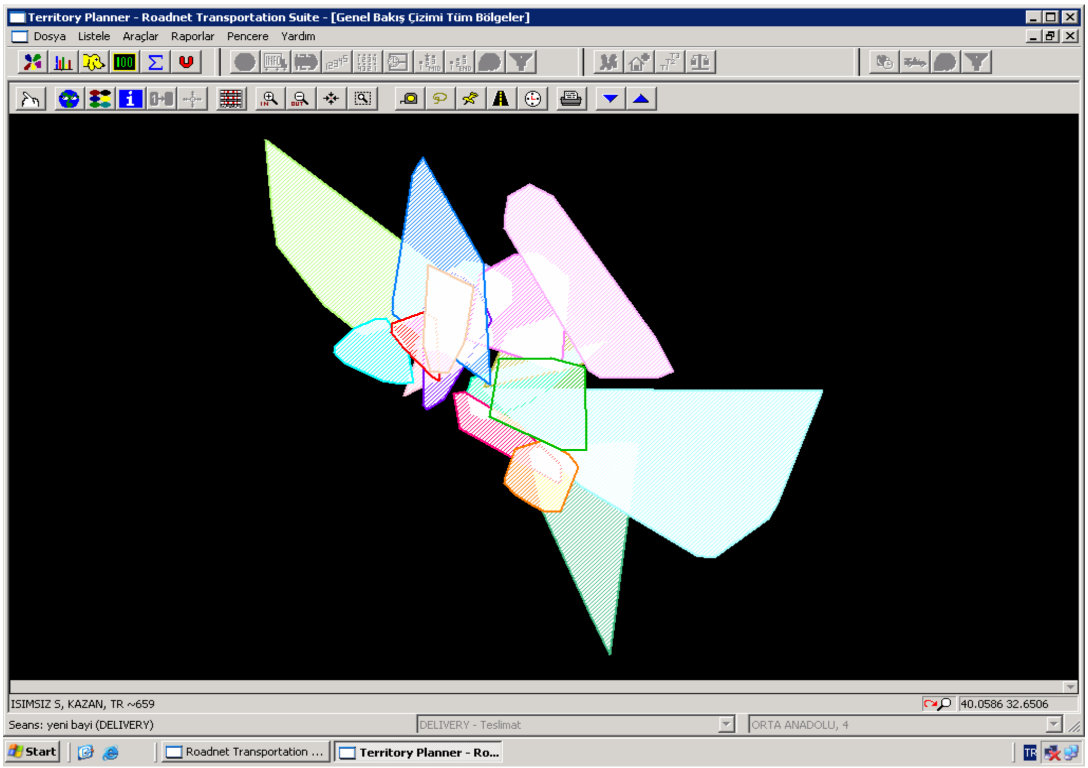


Figure 8.5 Overlapping areas

8.2.2.1Make Territories

Table 8.3 summarizes making territories options.

Table 8.3 Making territories options

Make Territories		
Secondary criteria	**Alias of secondary criteria**	**Weighting factor**
Balanced sales	1	0(Off) to 9(High)
Balanced service times	2	
Balanced number of locations	3	
Balanced number of stops	4	
Balanced number of run times	5	
Minimal territory overlap	6	

To make territories “Account Guidelines page” and “Depots page” is not used. The “Account Guidelines page” lets you specify which account types must be included in every territory, and how many must be in each territory. This option is not necessary for the application. “Depots page” is only used if there are more then one depot.

8.2.2.2 Assign Days

"Time windows page" is not used for the application. In some sectors time windows are very important and distributors must deliver goods on time. In this application time windows are not taken into account. It is assumed that customers are available through the route duration.

Optimization parameters page:"Optimization Completion Criteria" area is not used, because using these options may cause Assign Days to stop working before the best solution has been found.To indicate how hard the optimization process should work, it is necessary to choose Optimization Effort Level. The higher the optimization level, the longer the optimization process will take. In order to complete the optimization process within reasonable time, level 3 is selected for all scenarios.

Time parameters page:In maximum run length field 00:00 is entered for all scenarios, because any customer that cause a route to exceed its maximum run length will be unassigned and will not be placed on other routes. Selecting 00:00 is provided there will be not any unassigned customer.

Advanced parameters page:
Number of Optimization Passes :200
Number of Moves to Look Ahead:2
"Quit Recursion when First Better Move Found" is checked for all scenarios.
Number of Grid Squares Along a Side,Large Count:64, Medium Count:32 ,the Small Count:6
Cluster Duplicate Latitude/Longitudes is selected.
Precision Factor:0
Method for Laying out the Regions for the Routes: spokes

Load parameters page:
Daily Load Distribution Goal Percentages area is not used because there is no need to use this area.

Primary Balance Size area:sales is selected for all scenarios

“Route capacity restrictions area” and “Use equipment capacity” is not checked in order to not allow unasssigned customers.

Table 8.4 and 8.5 shows options of assign days.

Table 8.4 assign days options 1

Assign days		
Score weighting parameters	**Alias of parameter**	**Weighting factor**
Importance of balancing route length	1	1(low) to 10(high)
Importance of balancing load	2	
Importance of minimizing cost	3	

Table8.5 assign days options 2

Assign Days	
Optimization Effort Level	1(low) to 5(high)

Scenario 1:

Figure 8.6-8.10 show the parameters which are selected for scenario 1.

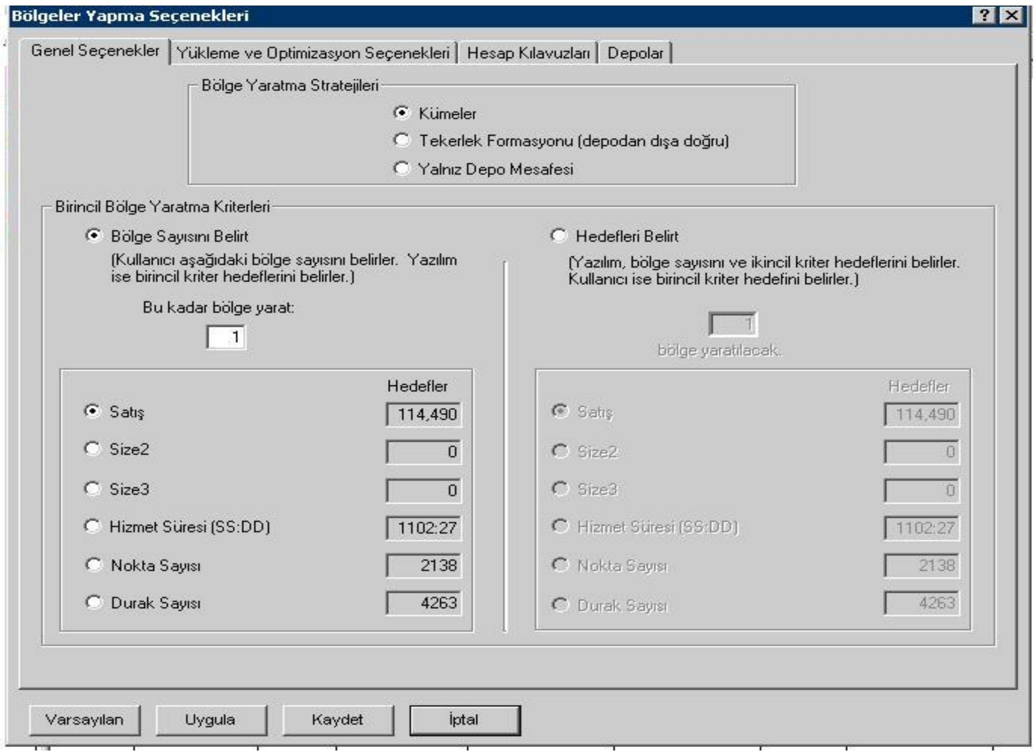


Figure8.6 General options

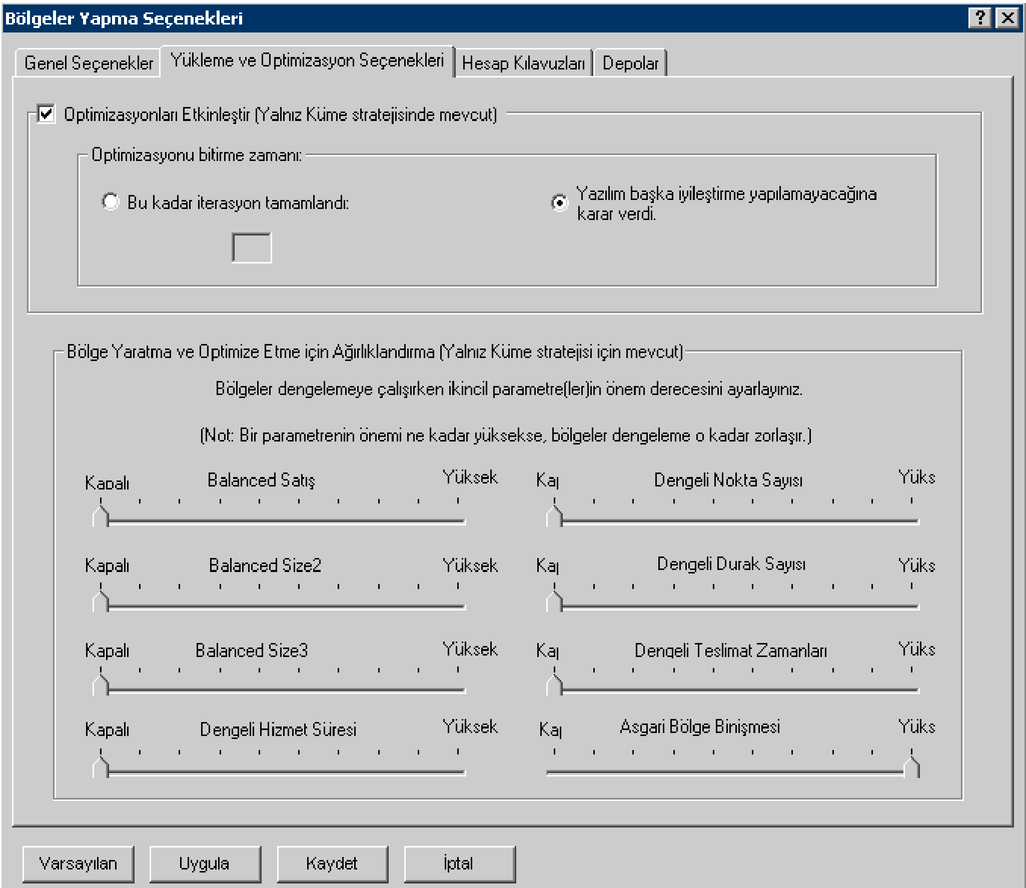


Figure 8.7 Optimization options

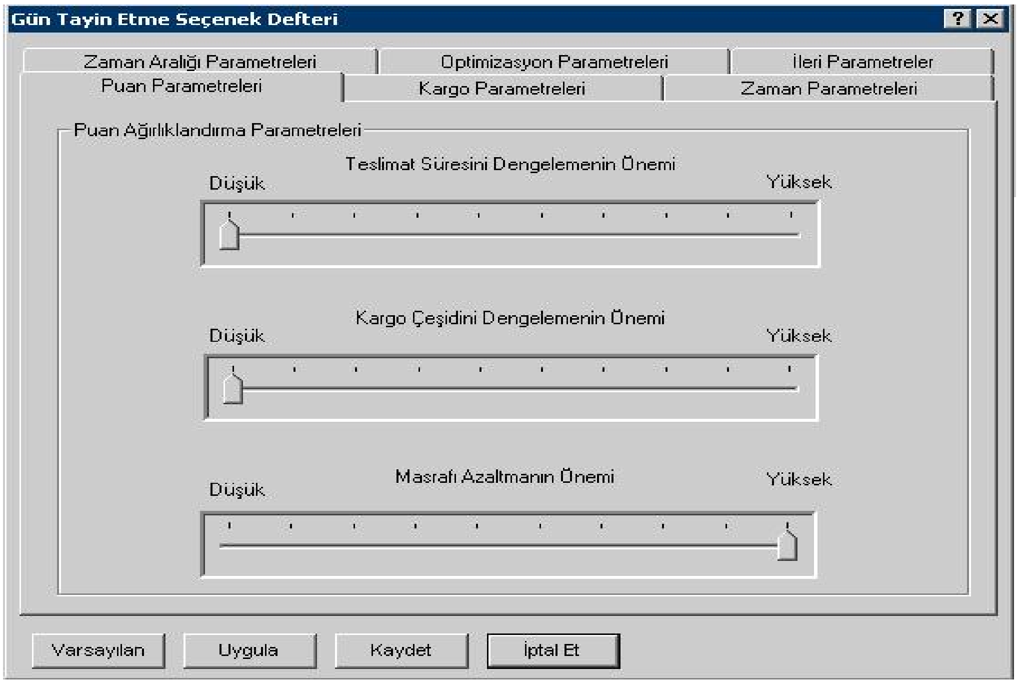


Figure 8.8 Score parameters

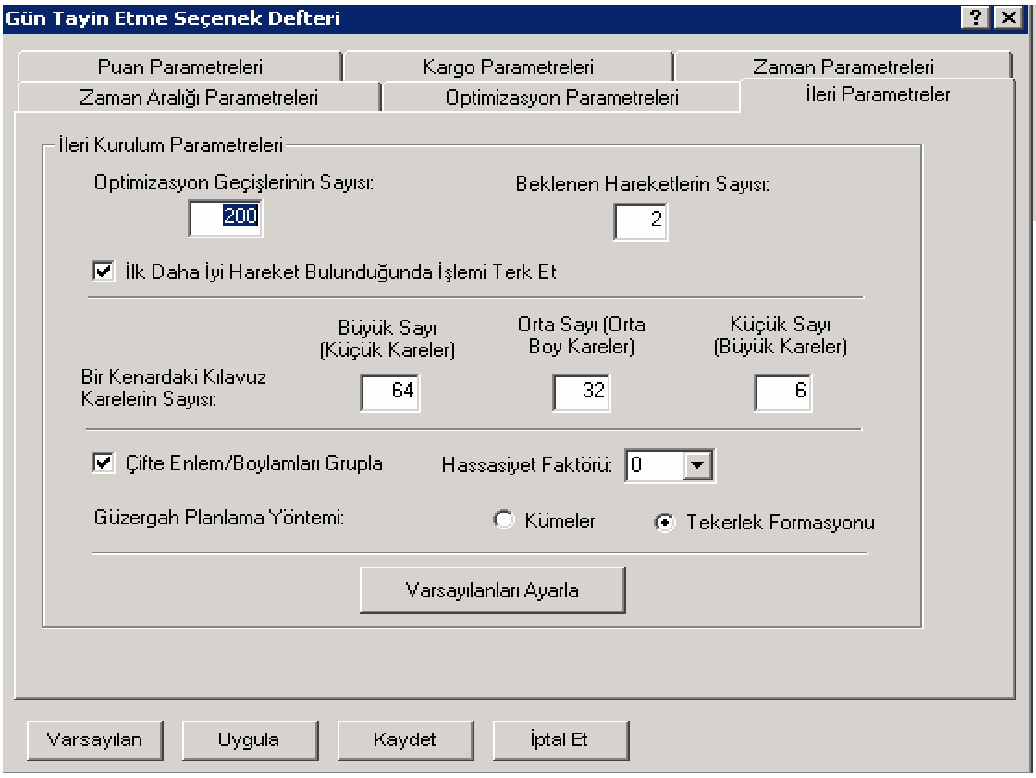


Figure8.9 Advanced parameters

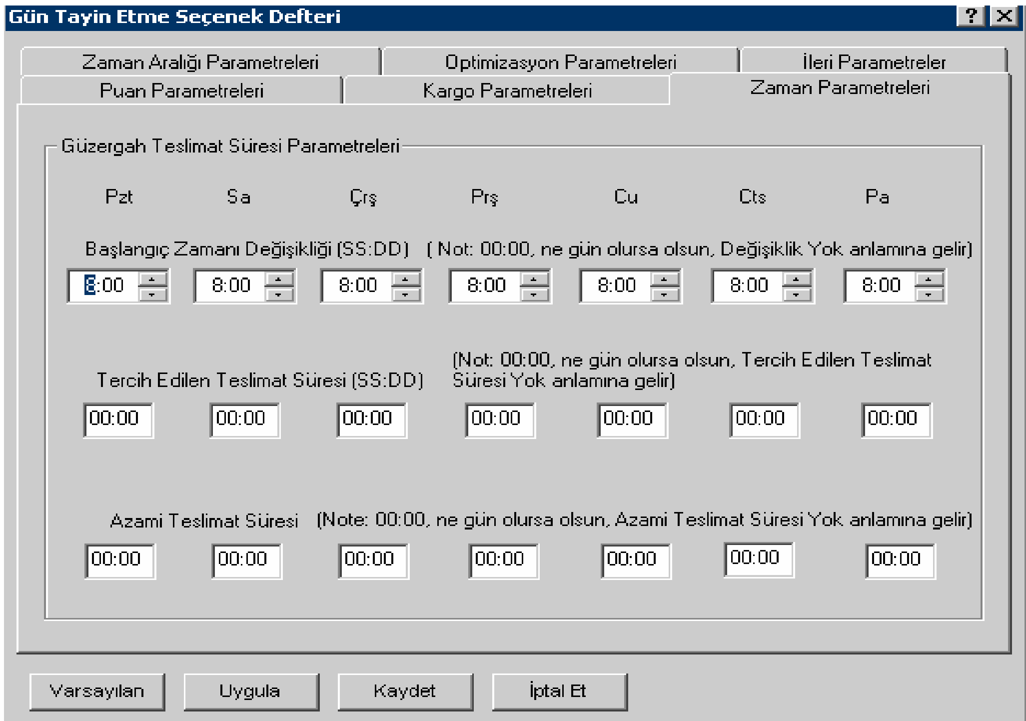


Figure 8.10 Time parameters

Table 8.6 and 8.7 summarize selected options for 10 scenarios.

Table 8.6 Summarizes selected make territories options for scenarios

Make territories							
	general options	weighting and optimization options					
Scenario	strategy for creating territories	1	2	3	4	5	6
1	clusters	0	0	0	0	0	9
2	clusters	0	9	0	0	0	9
3	clusters	0	0	9	0	0	9
4	clusters	0	9	9	0	0	0
5	spokes	0	0	0	0	0	0
6	clusters	9	0	0	0	0	9
7	clusters	0	5	0	0	0	9
8	clusters	0	0	0	5	0	9
9	clusters	0	4	4	0	0	9
10	clusters	0	0	0	0	9	9

Table 8.7 Selected scenario options for assign days

assign days			
	Score weighting parameters		
Scenario	1	2	3
1	1	1	9
2	1	1	9
3	1	1	9
4	9	1	8
5	9	1	5
6	1	1	9
7	1	1	9
8	1	1	9
9	5	1	7
10	5	1	9

Table 8.8 shows results of scenarios. Figure 8.11 shows the results of the scenario1.

Table 8.8 Results

Scenario Number	Total Cost(YTL)	Total Distance(km)	Travel Time
1	8152	7621	790:33:00
2	8170	7633	789:54:00
3	8177	7647	791:34:00
4	8828	8650	814:56:00
5	8962	8853	819:11:00
6	**8149**	**7611**	**789:47:00**
7	8156	7630	790:09:00
8	8171	7646	790:58:00
9	8766	8555	812:54:00
10	8359	7947	799:49:00

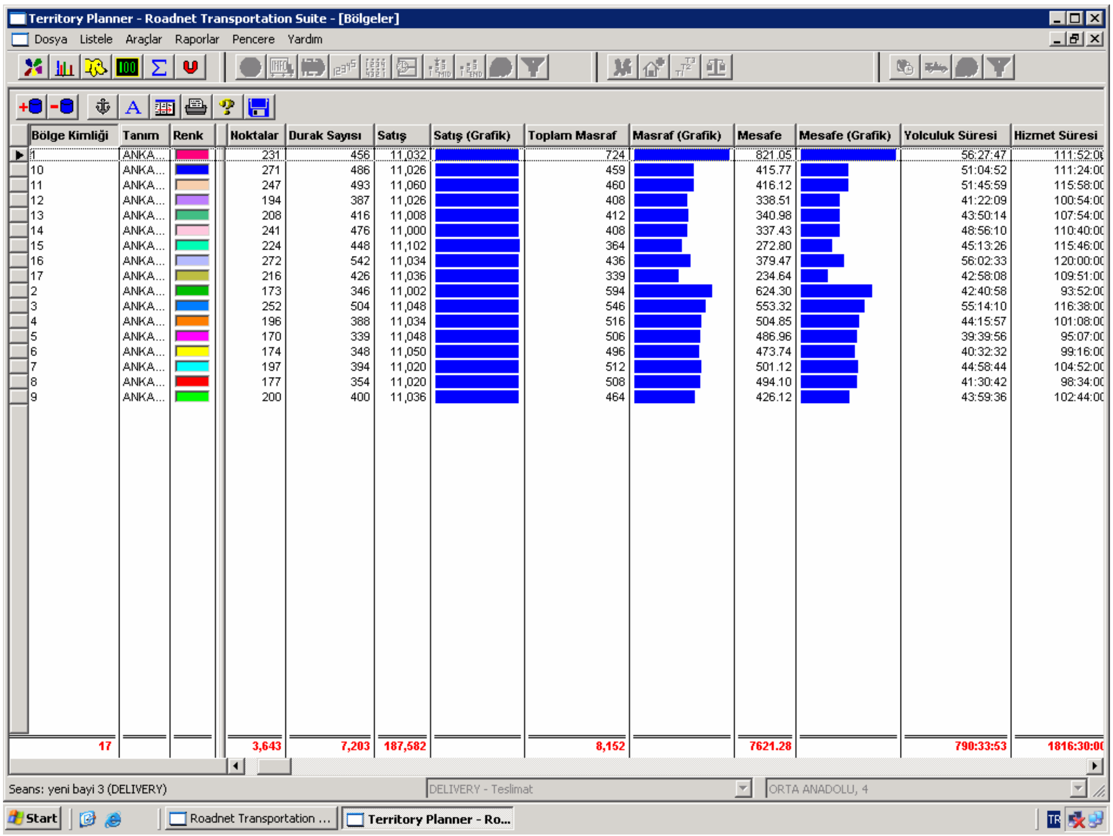


Figure 8.11 The results of the scenario 1

The sixth scenario is chosen as the best scenario. Comparison between current system and scenario 6 can be seen below Table 8.9.

Table 8.9 Comparison between current and scenario 6

	Total Cost(YTL)	Total Distance(km)	Travel Time
Current	10244	10813	880:46:00
Scenario 6	8149	7611	789:47:00
Improvement(%)	20%	29%	10%

Figure 8.12 shows the results of the Scenario 6

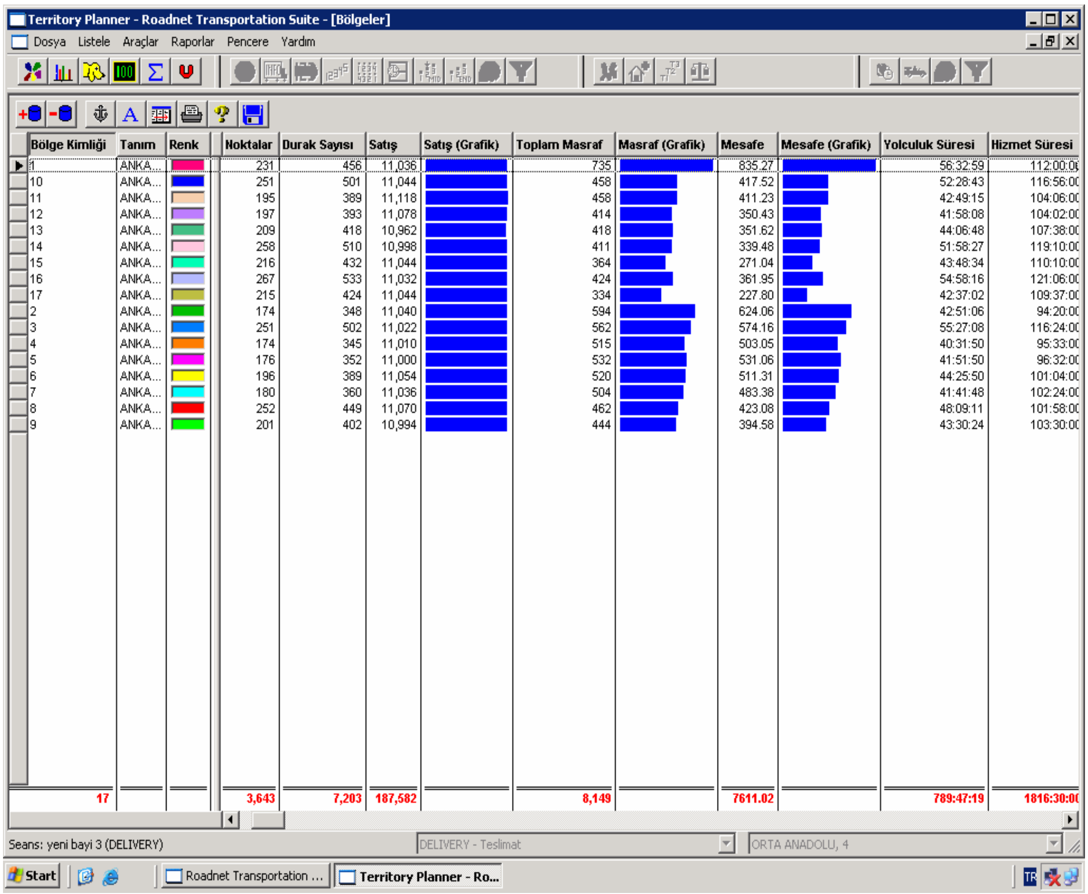


Figure 8.12 results for scenario 6

Figure 8.13 shows new boundries of the territories. As can be seen below overlapped areas decreases significantly.

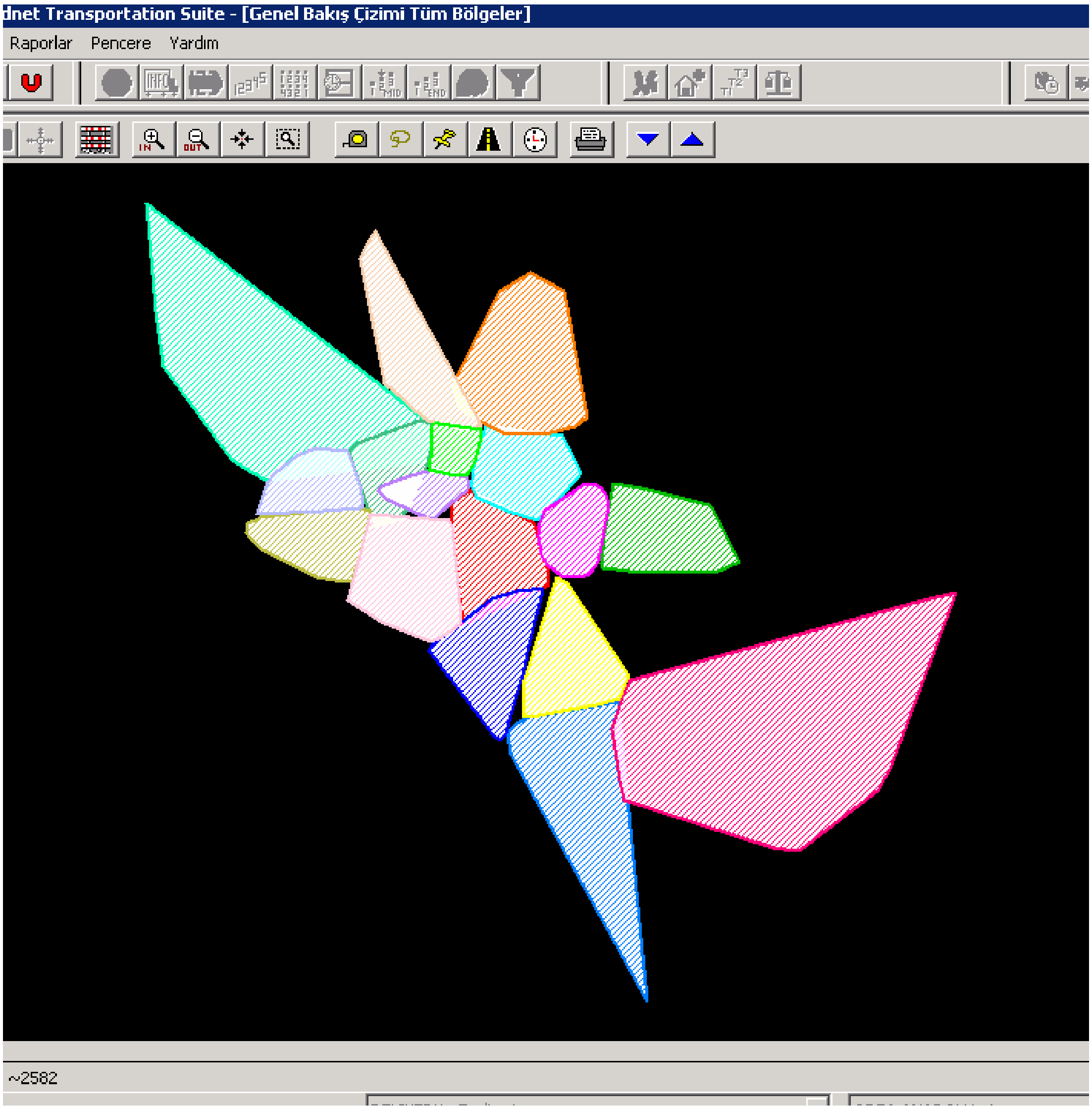


Figure 8.13

Selecting 10 territories from 17 territories is showed Figure 8.14 and Figure 8.15.

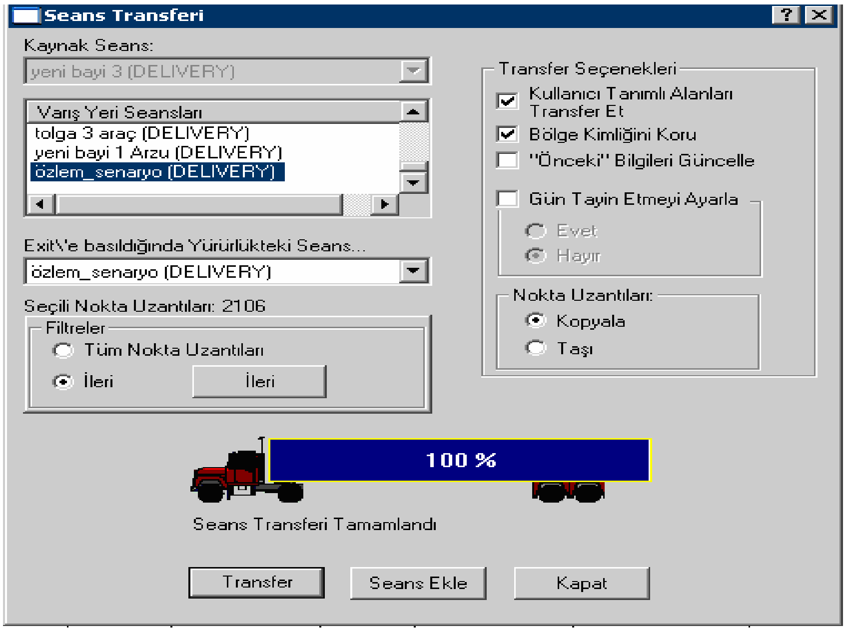


Figure 8.14 Selecting 10 territories from 17 territories

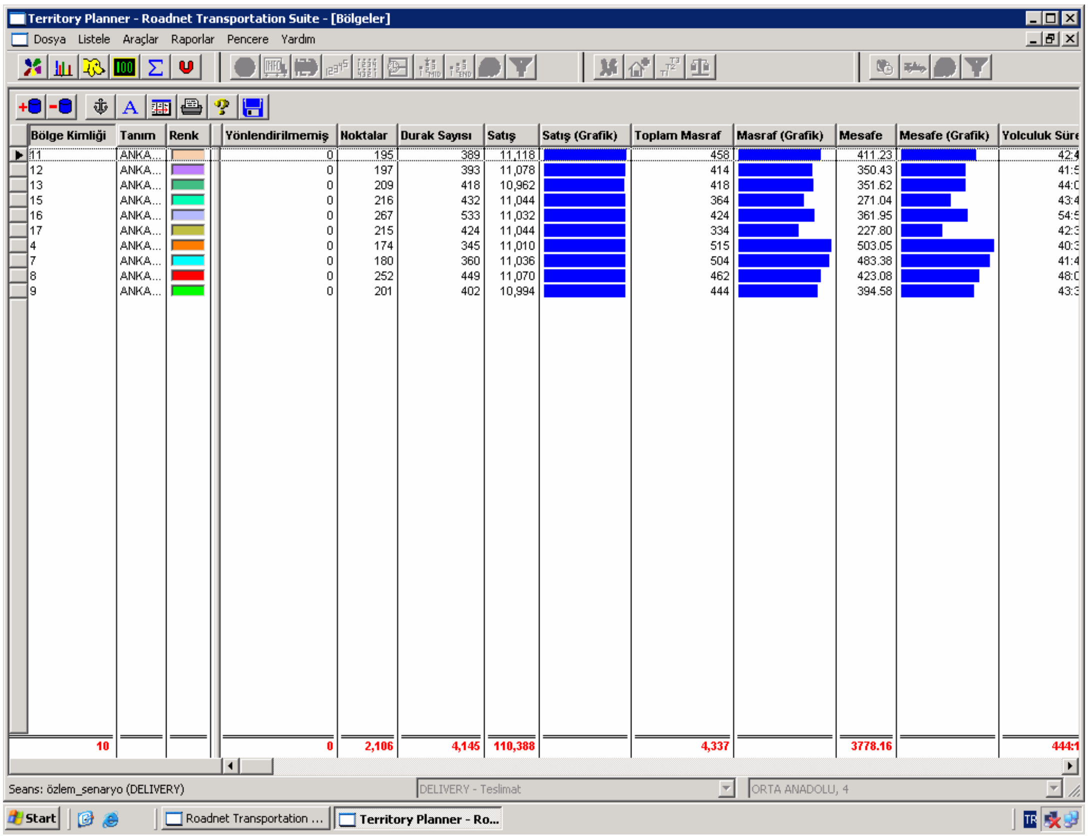


Figure 8.15 the territory which includes 10 vehicles.

The map of the selected area can be seen Figure 8.16

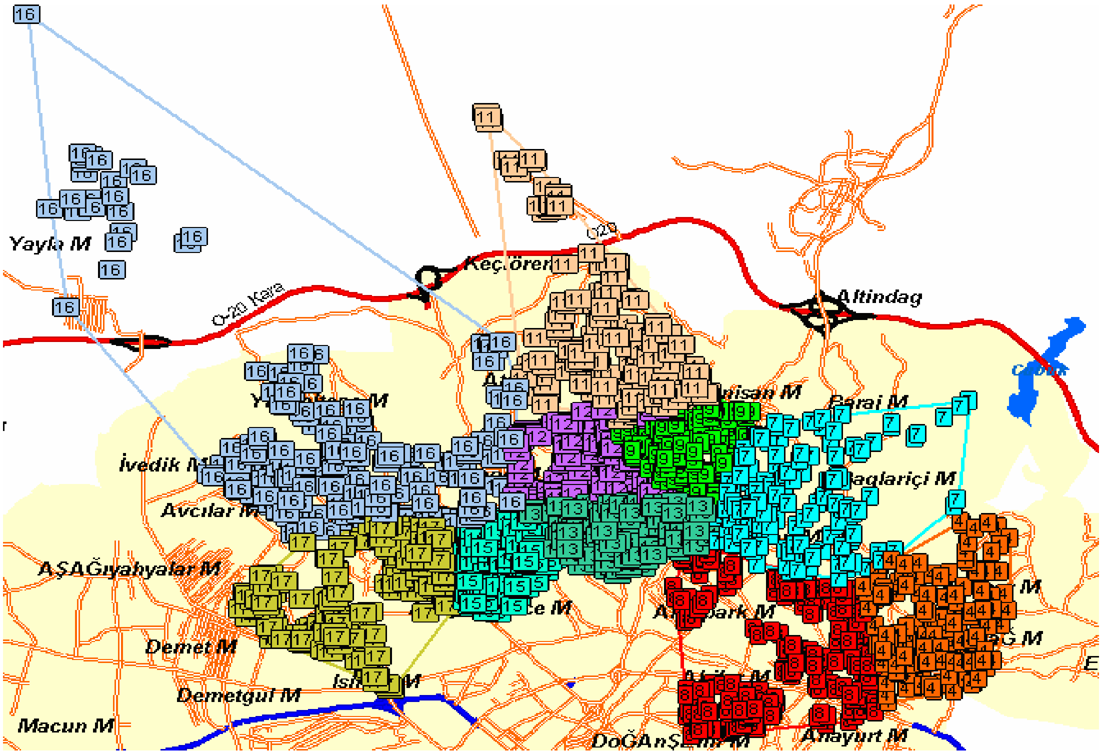


Figure 8.16 Map of the new distributor's territory.

The selected area is reoptimized by using Scenario 6's parameters. The results can be seen in table 8.10.

Table 8.10

	Total Cost(YTL)	Total Distance(km)	Travel Time
Current	4337	3778	444:10:00
Reoptimized	4332	3773	443:45:00
Improvement(%)	0,11%	0,13%	0,09%

8.2.2.3 Fine Tuning

Figure 8.17 shows weekly routes of a territory. Figure 8.18-8.20 shows daily routes of two vehicles and 8.19 and 8.21 shows after the fine tuning.

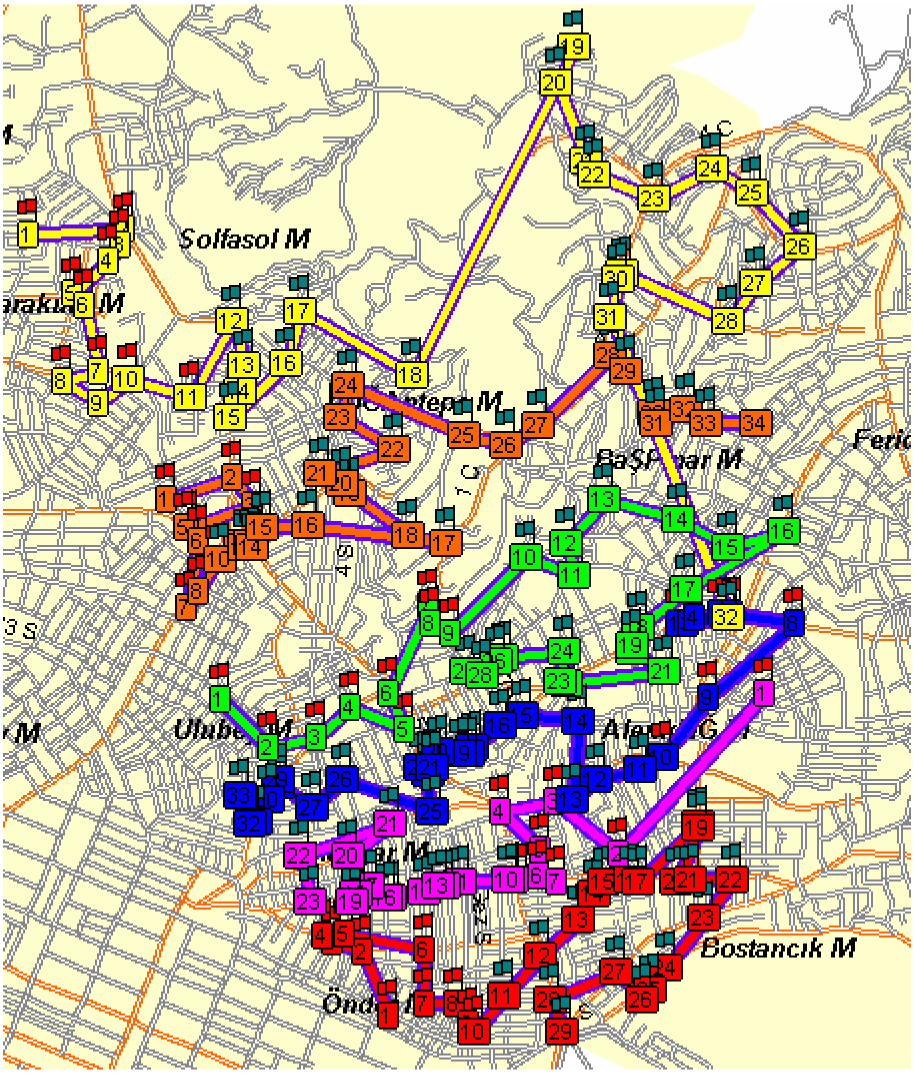


Figure 8.17 weekly routes of a territory

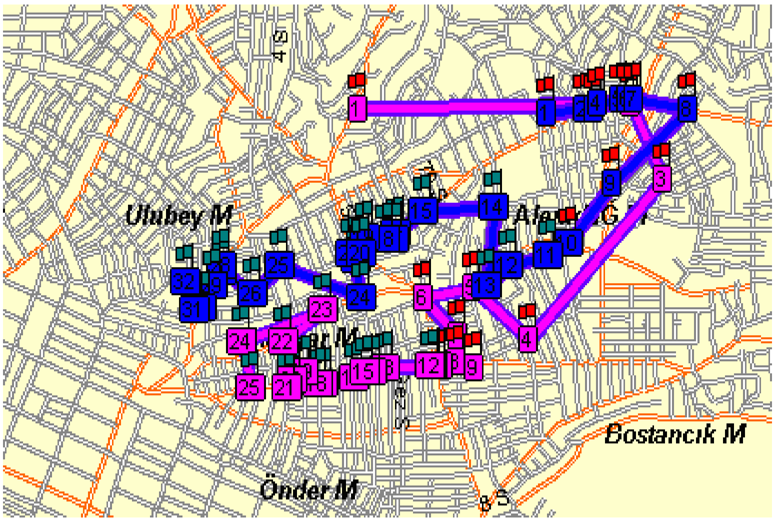


Figure 8.18 Current routes

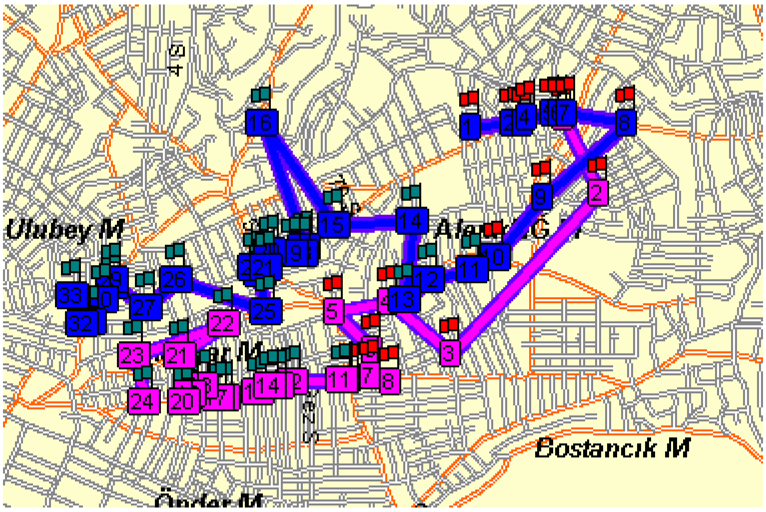


Figure 8.19 After the fine tuning

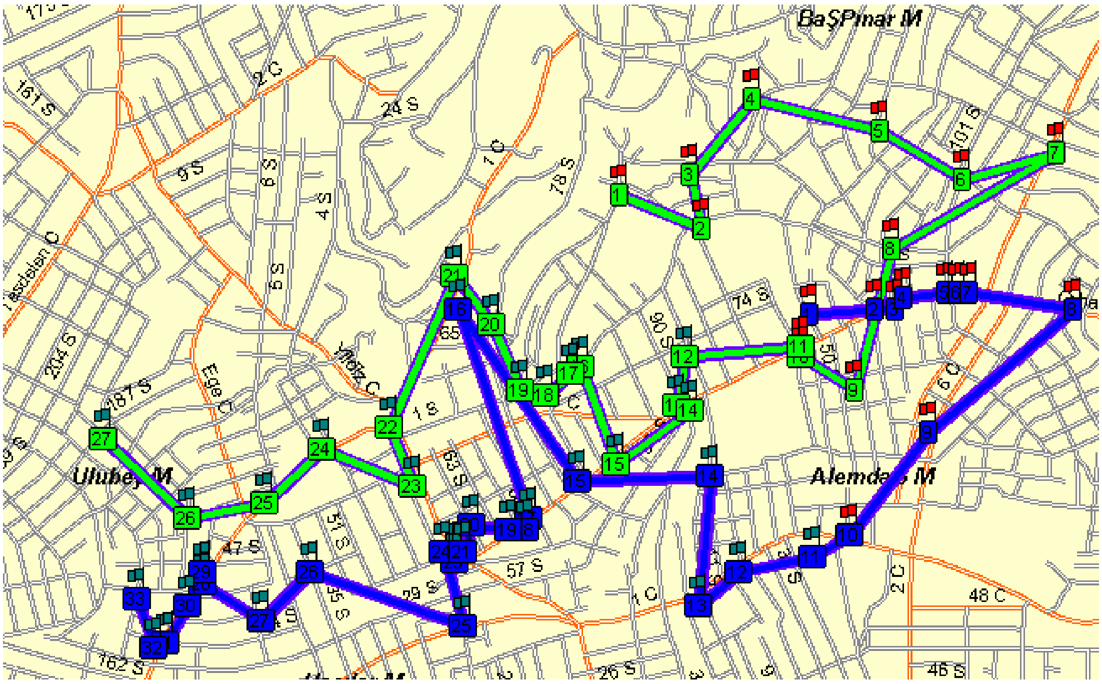


Figure 8.20 Current routes

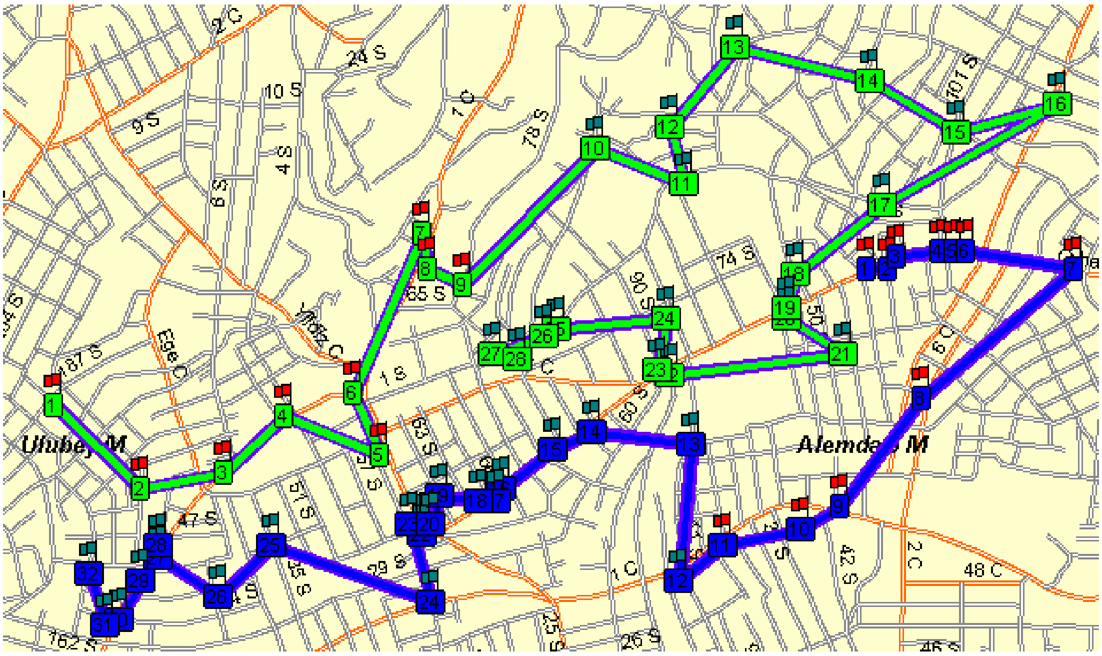


Figure 8.21 After the fine tuning

Figure 8.22 shows the results of fine tuning.

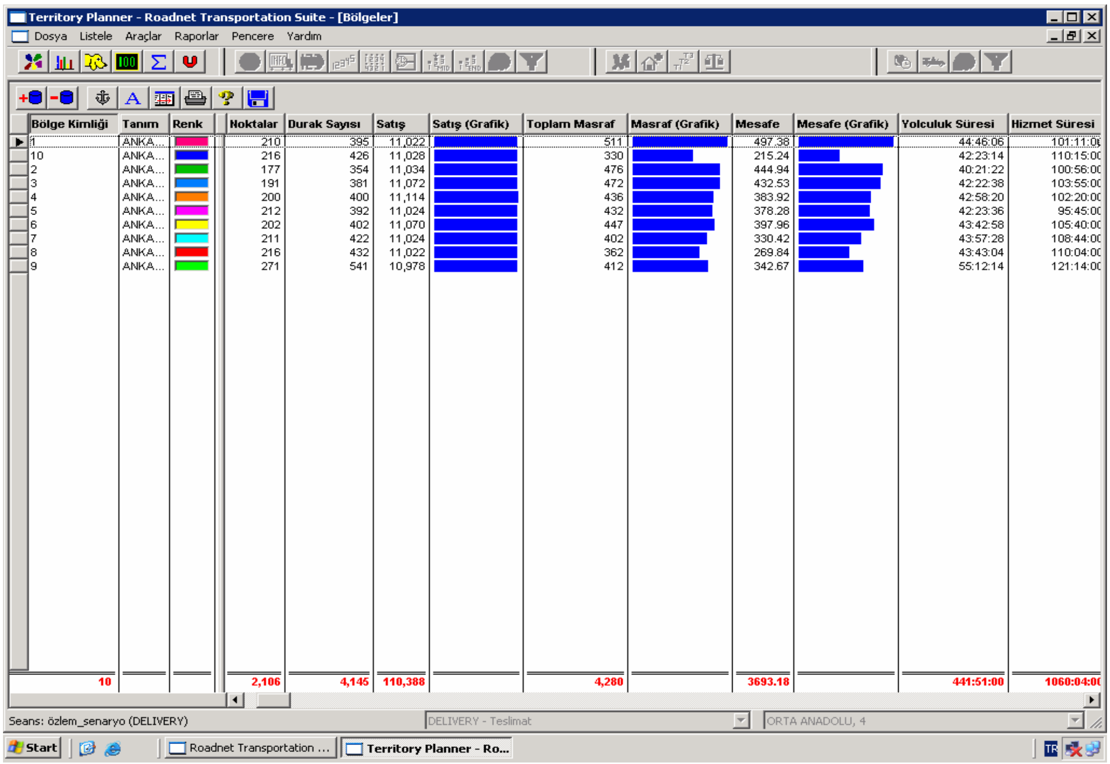


Figure 8.22 Result table of fine tuning

The comparison between reoptimization and fine tuning can be seen in Table 8.11. Fine tuning does not provide a significant improvement in numbers, but it increases drivers motivation and morale.

Table 8.11

	Total Cost(YTL)	Total Distance(km)	Travel Time
Reoptimized	4332	3773	443:45:00
After fine Tuning	4280	3693	441:51:00
Improvement(%)	1.2%	2.12%	0.42%

8.3 Algorithms For Decreasing Traveling Cost

8.3.1 Examination of Customer Selection and Profit Maximization

It is a usual characteristic that every customer has to be serviced in TSP and VRP and no value is associated to the service. However, some problems propose to select customers depending on a profit value that is gained when the visit occurs. We called this problems as Traveling Salesman Problems with Profits (TSPs with Profits), when a single vehicle is involved. For more than one vehicle the problems are called Routing Problems with Profits. TSPs with Profits are a variant of the Traveling Salesman Problem (TSP) where it is not necessary to visit all nodes. With each node is associated a profit. The objective of the TSPs with Profits is the simultaneous optimization of the collected profit and the travel costs.

8.3.1.1 Discard Nonpositive Marginal Profits Algorithm

The algorithm is proposed to maximize profit by Aksen (2004). Customer selection is caused to lost demand. The question is: Is customer i worth keeping (inserting) between nodes k and l?

Predecessor of customer node i : node k

Successor of customer node i : node l

πi:Unit profit

Figure 8.23 presents customer sequencing of route r

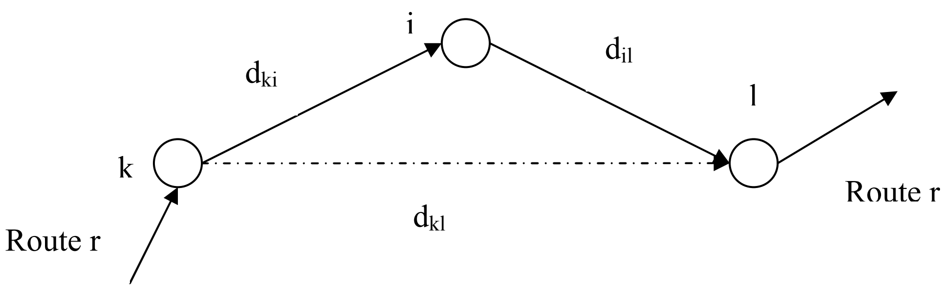


Figure 8.23 Customer sequencing of route r

Marginal Profit of customer i = $\pi i \times Dem_i - Unit\_Travel\_Cost \times (d_{ki} + d_{il} - d_{kl})$

Step1:For the current set of routes R compute each customer's marginal profit value $M\pi_i$. Sort $M\pi_i$ values in nondecreasing order.

Step2: $M\pi_{[0]}$, first marginal profit in the stack which belongs to customer $i_{[0]}$ is positive then stop.0/ w go to step 3.

Step3:Let $succ_i$ and $pred_i$ be the successor and predecessor nodes of customer $i_{[0]}$ on its current route r_i resp. Delete $i_{[0]}$ from r_i. Update the $M\pi$ values of $succ_i$ and $pred_i$ if they are customer nodes. Cancel route r_i if $i_{[0]}$ was the only customer on it.

Step4: Set $M\pi$ value for $i_{[0]}$ to infinity. Restore the nondecreasing order of $M\pi$ values in the stack and go to step 2.

Applying Discard Nonpositive Marginal Profits Algorithm manually is suitable for small instances. The application area includes 3643 customers. So we need a short cut. As can be seen in Figure 8.24 , the customers are located very close. The average distance between two consecutive customers is 300m. The customer (Customer x) which is displayed with a red arrow is the farthest point. It is 2,18 km far away from the closest customer.It can be seen in Figure 8.23. We assume that serving to the customer x takes 4,36km(2,18x2) totally. Fuel cost of vehicles per km is 0,65 YTL. The cost of serving customer x is 4,36x0,65=2,834YTL.

Deleting customer x is proposed to Frito-Lay. However, it is said that deleting a customer is a not desired action according to Frito-Lay's customer relationship rules. If serving a customer is not profitable, Frito-Lay will change visit frequency to customers.

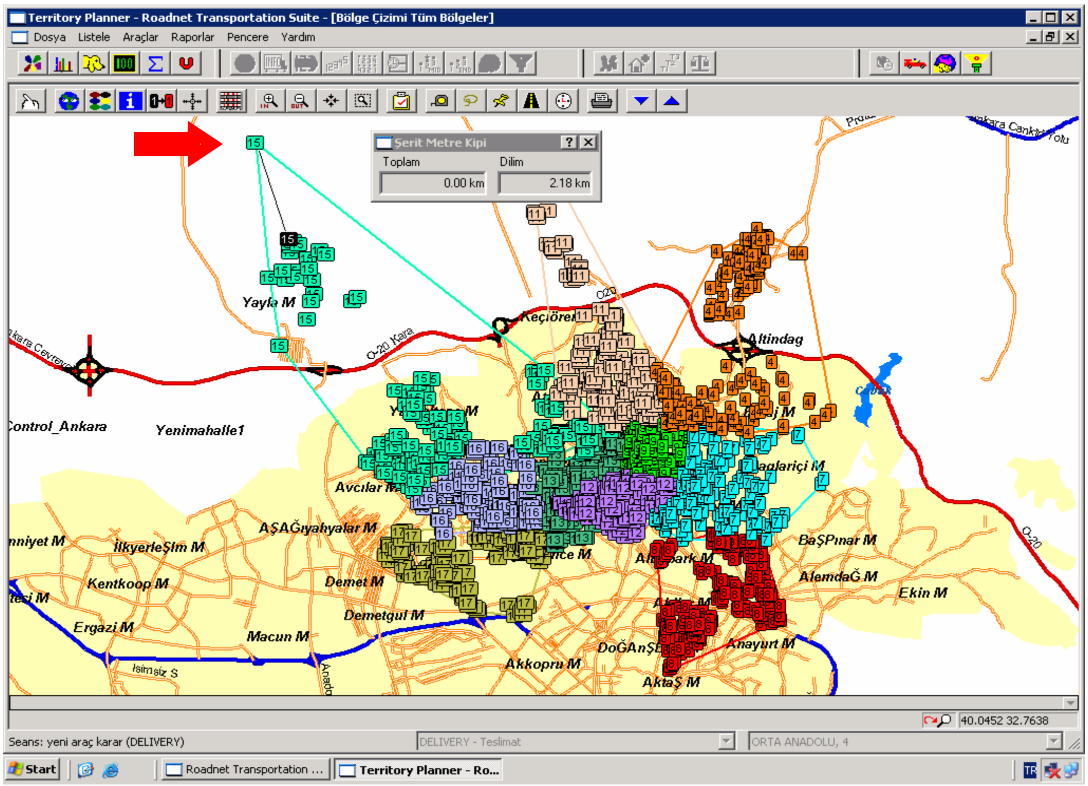


Figure 8.24

8.3.2 Changing Customer Visit Frequency Algorithm

In this study a new algorithm is proposed. The aim of the algorithm is decreasing traveling cost by changing customer's visit frequency.

$E_{ij:}$daily endorsement of vehicle i for day j   i:1,…..n j:1,….,6

$C_{ij:}$total cost of vehicle i for day j

$R_{ij:}$ route of vehicle i for day j

Steps of the Algorithm

Step1:List daily average endorsement of each vehicle.

Step2:List daily average cost of each vehicle.

Step3:Compute for each vehicle the difference between daily endorsement and daily total cost.

Step4:If the diffence is smaller than Break-Even point(**907YTL)**,change visit frequency.

Table 8.12, 8.13, 8.14 show computations for steps of the algorithm.

Table 8.12 Daily average endorsement of each vehicle

	Days					
Vehicle Number	1	2	3	4	5	6
1	971	993	1180	961	999	1145
2	855	967	1076	993	1080	1201
3	982	1168	1165	1065	1127	1128
4	1003	1005	1036	966	1011	995
5	1012	962	1074	1025	971	977
6	1086	916	1090	1024	1048	1023
7	1021	985	973	1059	976	947
8	1065	947	977	1037	993	999
9	987	1060	1001	1286	854	984
10	1071	987	1164	957	1096	963

Table 8.13 Daily average cost of each vehicle.

	Days					
Vehicle Number	1	2	3	4	5	6
1	51	56	47	54	62	49
2	45	55	56	56	61	52
3	55	66	66	60	64	64
4	48	50	50	53	50	50
5	57	54	61	58	53	52
6	61	52	62	52	59	58
7	54	56	52	54	55	53
8	52	51	44	54	50	47
9	37	60	43	46	48	46
10	61	53	51	49	62	47

Table 8.13 Difference between daily endorsement and daily total cost.

	Days					
Vehicle Number	1	2	3	4	5	6
1	920	937	1133	907	937	1096
2	**810**	912	1020	937	1019	1149
3	927	1102	1099	1005	1063	1064
4	955	955	986	913	961	945
5	955	908	1013	967	918	925
6	1025	**864**	1028	972	989	965
7	967	929	921	1005	921	**894**
8	1013	896	933	983	943	952
9	950	1000	958	1240	**806**	938
10	1010	934	1113	908	1034	916

According to the algorithm four route's visit frequency should be change. They are showed as bold above table.(R_{21},R_{62},R_{95},R_{76}) Two visits per month are enough for these routes. This algorithm helps to decrease total cost of distribution.

CHAPTER NINE
CONCLUSION

9.1 Performed Research

Manual methods for designing territories and routing vehicles are prone to error and time consuming. In the literature several algorithms is proposed to solve these problems. Most of the algorithms are not directly applicable to real life problems which usually incorporate many side constraints.

The significant development of computer technology and the introduction of Geographic Informations Systems are aided presenting lots of commercial packages to the market. Real life problems can be solved near-optimally using a commercial package.

The purpose of the study was optimizing the delivery routes of Frito Lay Ankara distribution center and decreasing fuel cost of the company. First an integer linear programming model is developed to solve Frito Lay’s period vehicle routing problem. The size of the problem hinder solving the problem within reasonable time. A heuristic or a software should be used to solve such a enormous size problem. To reach this purpose Territory Planner is used as an optimization tool. 10 different scenarios applied to the selected territory and scenario 6 is selected as the best. To decrease fuel cost a new algorithm is also proposed. The aim of the algorithm is decreasing traveling cost by changing customer’s visit frequency.

After the application the overlapped areas of territories is decreased significantly. All visits are planned according to customer’s predefined visit frequency. Equilibrium conditions are satisfied according to company’s preferences. According to the Table 8.9, total cost 20% decreased by, total distance traveled is decreased by 29%, travel time is decreased by 10%.

9.2 Future Research

There is a great deal of study to be made on vehicle routing problem. However, in Turkey there are a few studies about VRP and vehicle routing solutions has not been considered as a scientific support to business and still only used by big companies. Therefore there are many research opportunities in Turkey.

Approximately 75% of all the transportation of goods is done by vehicles. Using efficient vehicle routing solutions can be aided decreasing traffic problem, increasing profitability of companies and customer satisfaction.

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APPENDIX A

SERVICE PATTERN SET

	Mo	Tu	We	Th	Fr	Sa	Mo	Tu	We	Th	Fr	Sa
pattern	1	2	3	4	5	6	8	9	10	11	12	13
1	1	0	0	0	0	0	1	0	0	0	0	0
2	0	1	0	0	0	0	0	1	0	0	0	0
3	0	0	1	0	0	0	0	0	1	0	0	0
4	0	0	0	1	0	0	0	0	0	1	0	0
5	0	0	0	0	1	0	0	0	0	0	1	0
6	0	0	0	0	0	1	0	0	0	0	0	1
7	1	0	0	0	0	0	0	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	0	0	0	0	0
11	0	0	0	0	1	0	0	0	0	0	0	0
12	0	0	0	0	0	1	0	0	0	0	0	0
13	1	0	0	1	0	0	1	0	0	1	0	0
14	0	1	0	0	1	0	0	1	0	0	1	0
15	0	0	1	0	0	1	0	0	1	0	0	1