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# Process improvement applications for a cargo company

## Bir kargo şirketi için süreç iyileştirme çalışmaları

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**Abstract**

In this study, system analysis and improvement applications in a cargo company have been considered and some problems have been detected in the company`s current system. In the content of this study, multi-criteria decision-making methods have been implemented to select a vehicle and intra-vehicle shelf type to solve problems about space usage, time losses and package damage due to incorrect vehicle type and absence of intra-vehicle shelf. Besides, to minimize transportation costs which impose significant expenses to the company, the vehicle routing problem is considered with the help of the GAMS (General Algebraic Modelling System) program. In vehicle routing problem, it is aimed at one transfer center to eighteen branches, under the demand, amount of vehicle and capacity of vehicle constraints. While concerning the set of problems that exist in the company`s current system, it`s attempted to provide a more effective system.

**Keywords:** System analysis and improvement, Vehicle route problem, GAMS, Multi-criteria decision making

**Özet**

Bu çalışmada, bir kargo şirketinde sistem analizi ve iyileştirme uygulamaları dikkate alınmış ve şirketin mevcut sisteminde bazı sorunlar tespit edilmiştir. Bu çalışma kapsamında, niteliksiz araç tipi kullanımı ve araç içi raf bulunmamasından kaynaklanan verimsiz alan kullanımı, paketleri araca yükleme ve indirme işlemi sırasında oluşan zaman kayıpları ve paket hasarı gibi problemleri çözmek amacıyla çok kriterli karar verme yöntemleri uygulanarak şirket için en uygun araç ve seçilen araca uygun araç içi raf tipi seçimi hedeflenmiştir. Ayrıca, GAMS programı yardımıyla şirket için büyük maliyet oluşturan dağıtım maliyetini en aza indirmek için araç rotalama problemi ele alınmıştır. Talep, taşıt miktarı ve taşıt kapasite kısıtlarına göre bir transfer merkezinden on sekiz şubeye rotalar yeniden oluşturulmuştur. Şirketin sisteminde mevcut olan sorunlar kümesi ile ilgilenerek, daha etkili bir sistem sağlamaya çalışılmıştır

**Anahtar Kelimeler**: Sistem analizi ve iyileştirme, Araç rotalama problemi, GAMS, Çok kriterli karar verme

## 1 Introduction

A System is a general set of parts, components or steps which are connected to form a complex whole. For instance, a business is a system that is made up of methods, routines, procedures; or a computer system that contains processors, memory, power of supply, etc [1].

System Analysis is the process of collecting and evaluating the facts, determining the problems, decomposition to parts of the system to see the parts which cause problems. Another perspective of system analysis is the evaluation of a current system to determine the areas which need improvements. Systems analysis is to understand how the system runs [2].

There are several benefits of system analysis for companies. It helps companies to achieve organizational success for their particular goals; oversee their weaknesses and problems to manage them easily. Also, system analysis help companies to focus their strengths in the process of improvement with an improved quality of products or services [3].

In this study, process improvement applications have been considered and implemented for a specific cargo company. First, the cargo company`s current system has been analysed as main and sub-processes. Second, steps that cause inefficiencies and problems were identified and possible improvements were considered. The first problem which examined in the company`s current system is shuttle buses' costs, during transportation from the transfer center to the eighteen branches. The second problem observed in the current system is an absence of an intra-vehicle design which causes significant time loss and damage during the packages to be loaded into the vehicles, stacked in the vehicle and unloaded from the vehicle. Various methods such as Vehicle Routing Problem (VRP), Multi-Criteria Decision Making (MCDM) methods (Analytical Hierarchy Process (AHP), and Technique Order Preference by Similarity to Ideal Solution (TOPSIS)) have been performed to minimize or eliminate to overcome determined problems to create a more efficient system.

To overcome the shuttle buses` costs problem, the VRP approach was used by General Algebraic Modeling System (GAMS). Also, AHP and TOPSIS methods have been used to solve the absence of intra-vehicle design problems. There have been many studies in the literature on these concepts.

Min (1992) presented various benefits of using the AHP for the software selection decision. It has been attempted to select proper logistics software among four different alternatives with detailed criteria of cost, service and vendor by using the Expert Choice program [4].

To show the performance development of a Business Process Reengineering (BPR) technique in the airline's cargo handling process by quality service and speed, Khan

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(2000) studied with an international airport. As a result of redesigning of the cargo handling process with elimination as well as minimization of process wastes (delay, transportation, inspection, rework and storage, etc.), significant developments have been achieved [5].

Al-Harbi et. al. (2001) presents group decision-making using the AHP. The paper has presented the AHP as a decision-making method that allows the consideration of multiple criteria. By applying the AHP, the prequalification criteria can be prioritized, and a list of contractors can be made. So, the best contractors to perform the project selected [6].

Demireli (2010) determined the performance of state-owned commercial banks that operates extensively nationwide by using the TOPSIS method which is one of the multi-criteria decision-making methods. The result of the study was determined that the state-owned commercial banks that operate nationwide are being affected by the local and global financial crisis, the performance scores are continuously fluctuated based on foreign data and there are no superior improvements in this sector [7].

Bhutia and Phipon (2012) performed integrated AHP and TOPSIS approaches to select suppliers by considering the criteria of product quality, service quality, delivery time and price. They analyzed each criterion with AHP and use the obtained weights to the TOPSIS method to prioritize the suppliers [8].

To identify the systemic agents of individual bankruptcies a system analysis was used by Shi et al. (2018). Both macroeconomic factors and micro characteristics are covered. According to this study, macroeconomic factors and micro characteristics are both significant agents of individual bankruptcies. In addition to these agents, uncontrollable factors such as economic, political and social factors are very important as well [9].

Mavhura (2018) used a systems analysis approach to explore ways in which communities in the northern semiarid tropics of Zimbabwe are vulnerable to hydrometeorological threats. The results show that the communities are vulnerable to multiple hydrometeorological threats due to multiple interacting factors [10].

Göçken et.al. (2018), presented Time Window Vehicle Routing Problem (TWVRP). TWVRP is a type of the classic Vehicle Routing Problem (ARP) in which the customers with known demands, a known warehouse and a certain number of identical vehicles having identical capacity and characteristics. To provide service to customers within a certain period, TWVRP aims to minimize the total number of vehicles and vehicles. In addition to a type of genetic algorithm, which is a meta-heuristic method, has been proposed. It was tested whether the use of different heuristic methods to create initial populations in the genetic algorithm affected the desired outcome. The genetic algorithm using the sweeping algorithm gives more effective results [11].

Pisinger and Ropke (2018) presented heuristics based on a large neighborhood search. They used the local search method they term Large Neighbourhood Search (LNS) to solve the Vehicle Routing Problem [12].

Based on the literature, a process improvement is aimed for a cargo company within the scope of this study. In line with this goal, vehicle routing problem application and multi-criteria decision-making techniques were applied on various process steps. A holistic solution approach has been applied to the cargo company's process. Based on business problems, addressing more than one problem with more than one solution technique constitutes the original contribution of this study to both literature and practice.

## 2 Material and methodology

Under the information and observations from a mid-size cargo company; problems and appropriate improvements in the current system were performed

### *2.1 Vehicle Routing Problem (VRP)*

Route optimization is considered as determining the most cost-effective route for transportation vehicles which attempts to means find the shortest path between two points. In route optimization, the number and location of all stops, departure/arrival time difference and effective loading are included in models.

VRP attempts to design optimal routes from a starting point (depot) to a group of destinations with individual business-specific limitations, such as a limited number of vehicles, cost constraints, time windows, limitations of resources dealing with the loading process at the starting point. The first classic VRP is known as the traveling salesman problem (TSP) and in time it became more complicated [13].

GAMS is a helpful tool for mathematical programming and optimization that is the most productive way of implementing optimization models and decomposition methods for optimization problems [14]. Hence, GAMS is used to attempt to solve the VRP of this study.

Different approaches to VRP have created variations of VRP. The detailed classification of VRP has been illustrated in Table 1.

The objectives for VRP are defined as the minimization of the total path, total travel time, and the number of vehicles. Problem constraints may be as starting the routes from the warehouse and ending at the warehouse, serving each store with one vehicle at a time, or not exceeding the vehicle capacity with the total demand for customers on the same route.

Vehicle Routing Problems Mathematical Model:

The general mathematical expression of vehicle routing problems is specified below:

“Notations:

$K$ = number of vehicles

$n$ = number of customers to which delivery must be made. Customers are indexed from 1 to n and index 0 denotes the central depot.

$bk$= capacity (weight or volume) of vehicle k.

$ai$= size of the delivery to customer i.

$cij$= cost of direct travel from i to customer j.”

**Table 1**. VRP Classification [15].

| | |
|---|---|
| "VRP according to number of vehicles" | • "Single Vehicle Routing Problem"<br>• "Multiple Vehicle Routing Problem" |
| "VRP according to number of environments" | • "Static Vehicle Routing Problem"<br>• "Dynamic Vehicle Routing Problem" |
| "VRP according to routes" | • "Open-ended Vehicle Routing Problem"<br>• "Close-ended Vehicle Routing Problem" |
| "VRP according to routing times" | • "VRP with unlimited route"<br>• "VRP with limited route" |
| "VRP according to constraints | • "Capacitated Vehicle Routing Problems"<br>• "VRP with distance constrained"<br>• "VRP with time windows"<br>• "VRP with a different type of customers"<br>• "VRP with the mixed installation" |

Variables;

$$y_{ik} = \begin{cases} 1 & \textit{if the oder from customer i is delivered by vehicle k} \\ 0 & \textit{otherwise} \end{cases}$$

$$x_{ijk} = \begin{cases} 1 & \textit{if vehicle k travels directly from branch i to branch j} \\ 0 & \textit{otherwise} \end{cases}$$

$$\text{Min} \sum_{ijk} c_{ij}\, x_{ijk} \quad (1)$$

$$\sum_i a_i\, y_{ik} \leq b_k \qquad k = 1, K \quad (2)$$

$$\sum_k y_{ik} = \begin{Bmatrix} K, & i = 0 \\ 1, & i = 1, \ldots, n \end{Bmatrix} \quad (3)$$

$$y_{ik} = 0 \text{ or } 1,\ i = 0, \ldots, n \qquad k = 1, K \quad (4)$$

$$\sum_i x_{ijk} = y_{jk'} \qquad i = 0, \ldots, n \quad (5)$$

$$\sum_j x_{ijk} = y_{ik'} \qquad i = 0, \ldots, n \quad (6)$$

$$\sum_{ij\in S\times S} x_{ijk} \leq |s| - 1 \begin{Bmatrix} s \subseteq 1, \ldots, n \\ 2 \leq |s| \leq n-1 \end{Bmatrix} \quad (7)$$

$$x_{ijk} = 0 \text{ or } 1, \qquad \begin{Bmatrix} i = 0, \ldots, n \\ j = 0, \ldots, n \end{Bmatrix} \quad (8)$$

The objective function is defined in Equation (1). Constraints (2) - (4) presents that each route begins and ends at the starting point (customer 0 or depot), that every customer is escorted by a vehicle and the load assigned to a capacitated vehicle. If the $yik$ is set to satisfy (2) - (4), then for given $k$, constraints (5) - (8) state a TSP over the customers assigned to vehicle $k$. In literature, there are several mathematical models based on this generalized model and various constraints are added to solve more complex problems. [16]

### 2.2 *TOPSIS (Technique Order Preference by Similarity to Ideal Solution)*

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) was developed by Yoon and Hwang in 1980 and uses the basic approaches of the ELECTRE method. As a Multi-criteria decision-making method, TOPSIS aims that the chosen alternative is supposed to have the shortest distance from the ideal solution and the furthest distance from the negative ideal solution. [17]

In general, the TOPSIS algorithm starts with forming the decision matrix which represents the satisfaction value of each criterion of individual alternatives. Then, the prepared matrix is normalized and values in the matrix are multiplied with the weight of criteria. The next step includes the calculations of the positive-ideal and negative-ideal solutions with a distance measure. Lastly, the alternatives are prioritized based on their relative closeness to the ideal solution. [18]

### 2.3 *. Analytical Hierarchy Process (AHP)*

The Analytic Hierarchy Process (AHP) is introduced by Thomas Saaty (1980), is one of the popular MCDM methods to select the best alternatives among the options under certain decision parameters. In the AHP method, the problem and the main aim are defined first. In the second step, main and sub-criteria are formed with alternatives. TO compare alternatives under determined parameters are performed by using a comparison table which is presented in Table 2 [19]. Following the binary comparisons by a responsible, consistency ratio is calculated with the help of consistency index and random index. The consistency ratio is calculated with the help of consistency index and random index by division while the random index is prepared based on the number of criteria (n). The consistency index (CI) is calculated by deducting a number of criteria (n) from the largest eigenvalue of the considered matrix (λmax) and dividing it to n-1. The consistency ratio has to be less or equal to ten percent, if contrary, the comparison matrix has to be renewed [19].

**Table 2**. Pairwise comparison table [19]

| Rating | Description |
|---|---|
| 1 | *"Equal importance"* |
| 3 | *"Moderate importance of one over another"* |
| 5 | *"Strong importance of one over another"* |
| 7 | *"Very strong importance of one over another"* |
| 9 | *"Extreme importance of one over another"* |
| 2, 4, 6, 8 | *"Intermediate values"* |
| Reciprocals | *"Reciprocals for inverse comparison"* |

## 3 Results and discussions

This part consists of two sections as vehicle route improvement and intra-vehicle storage improvement. The vehicle route problem has been implemented from GAMS to find the optimal route, decrease costs and improve the current system. AHP and TOPSIS have implemented to choose better vehicle types for the company. Also, AHP has implemented to choose an intra-shelf type for the vehicle. This implementation can reduce time loss and damage to packages during the loading, stacking and unloading to vehicles.

### 3.1 *Vehicle route problem*

In this study, Vehicle Routing Problem applied to a cargo company for unsatisfying and expensive shuttle bus routing. These buses create expenses for the company. These expenses are aimed to be reduced in this study by decreasing the number of vehicles and creating the shortest and the most effective route for the vehicles with some constraints. The mathematical model used for transportation activity has convenient data for eighteen branches and one transfer centre, shown below.

Parameters:

*K:* Total vehicle number
*N*: Total branch number
*Cij*: Transportation cost from source i to destination j
*M(i)*: Branch demand on i
Indexes:
*i*: branch point i
*j*: branch point j
*k*: vehicle point k
Positive Variable:
*Tki*: satisfied branch demand on point i
0-1 Variable:
*xijk:* if transport k travels from point i to print j, then 1, else 0,
Constraints:

$$Min\ Z = \sum_{i=0}^{18}\sum_{j=0}^{18}\sum_{k=1}^{4} C_{ij}\, x_{ijk} \qquad (1)$$

$$\sum_{i=1}^{18} T_{ki} \le 18000 \qquad k = \{1,2,3,4\} \qquad (2)$$

$$\sum_{i=0, i\neq s}^{18}\sum_{k=1}^{4} x_{isk} = \sum_{j=1}^{18}\sum_{k=1}^{4} x_{sjk} \qquad s = \{1,2,\ldots,18\} \qquad (3)$$

$$\sum_{j=1}^{18} x_{0jk} \ge \sum_{i=0}^{18}\sum_{j=1, j\neq i}^{18} x_{ijk} \qquad k = \{1,2,3,4\} \qquad (4)$$

$$\sum_{i=1}^{18} x_{i0k} \ge \sum_{i=0}^{18}\sum_{j=1, j\neq i}^{18} x_{ijk} \qquad k = \{1,2,3,4\} \qquad (5)$$

$$\sum_{k=1}^{4} T_k = M_i \qquad i = \{1,2,\ldots,18\} \qquad (6)$$

$$\sum_{i=0}^{18}\sum_{j=1, i\neq j}^{18} x_{ijk}.M \ge \sum_{i=1}^{18} T_{ki} \qquad k = \{1,2,3,4\} \qquad (7)$$

$$x_{ijk} + x_{jik} = 1 \qquad (8)$$

$$x_{ijk} \in \{0,1\} \qquad (9)$$

These formulas indicate that (1) the objective function of this vehicle routing problem is to reach the minimum routing cost. Due to constraint (2), the total capacity of the vehicles should not exceed 17000. Constraint (3) means that the incoming branches should be equal to the outgoing branches since the vehicle does not stay at the stores. According to constraints (4) and (5), the vehicles should start the routes from the transfer center and end the route at the transfer center. Constraint (6) declares that the vehicle fleet should complete the demands of the branches on each route and also the routes should be enough to satisfy the demands as shown in constraint (7). Due to constraint (8), vehicles cannot visit the same branch twice. The last constraint, (9), demonstrates that variable Xijk can take just the 0 or 1 values.

To achieve the optimal solution for the objective function, the GAMS program has been used. In the current system, Ford Master is used in the vehicle fleet and fuel cost is 0.70 ₺ per kilometer. So, the daily fuel cost is 162.8 ₺. According to the GAMS solutions, the daily fuel cost of the suggested vehicle fleet is reduced to 136.76 ₺, which is almost 16% lower than the current fuel cost. The suggested model indicates more efficient vehicle capacity usage, less vehicle amount and effective routes than the current situation.

### 3.2 *Intra vehicle storage*

The vehicles which are used for the logistics industry may be in different dimensions and widths. The logistic firms choose the appropriate vehicle for their business according to the differences in vehicles. Especially minibusses and panel vans are used for intercity transportation, but the internal cab width of the vehicles may not be enough all the time according to dimensions or types of load. In case of insufficiency, some firms use in-vehicle shelving systems.

Intra vehicle shelving systems extend the usage of internal cab width by extra shelves, so the load volume may increase. There are many different choices of shelf materials according to the purpose of the load, such as metal, plastic, glass, etc. Also, locked cabinets are used in an in-vehicle shelving system for high-security loads.

Intra vehicle shelving system design depends on the need of area and purpose. Shelves may be small and many for tiny pieces; big and strong for electronic devices; or if the purpose of the vehicle is transporting pets, the shelves must be strong and also hygienic.

When the company's current system is examined, it is observed that the capacity of the vehicle is not used efficiently during the loading, sorting, and unloading of the packages and this situation causes a lot of time loss. In addition, because there are no shelves inside the vehicle, the packages are randomly put on the floor of the vehicle. Therefore, the packets may damage.

To improve this situation in the system, first of all, AHP and TOPSIS methods were used with four alternatives and four criteria to select a vehicle type.

### *3.2.1 Selecting the best vehicle using AHP and TOPSIS*

According to four alternatives (Ford Transit Van, Renault Master, Vw Crafter Panelvan, Mercedes Sprinter Panelvan) and four criteria (Capacity, Price, Suspension Softness and Fuel Usage) which are important and suitable for cargo vehicle types, AHP and TOPSIS methods are applied and select the best alternative for the company with two different methods. According to the scores and consistency analysis, the consistency ratio is calculated 0.0879 in AHP which reveals that results are consistent. The results are presented in Table 3.

**Table 3**. AHP and TOPSIS Results for selecting best vehicle

| Alternatives | AHP Results | TOPSIS Results |
|---|---|---|
| Ford Transit Van | 0.310 | 0.7569 |
| Renault Master | 0.151 | 0.2911 |
| Vw Crafter Panelvan | 0.152 | 0.4666 |
| **Mercedes Sprinter Panelvan** | **0.387** | **1.0000** |

According to the application of AHP and TOPSIS results, the result shows Mercedes Sprinter Panelvan is the best alternative for the company since it has the highest weight according to the AHP results. When all alternatives are compared with AHP and TOPSIS approaches, the second-best selection becomes the Ford Transit Van under the criteria of capacity, price, suspension softness and fuel usage. Vw Crafter Panelvan and Renault Master have the lowest weights according to the results.

### *3.2.2 Selecting the suitable shelf type with AHP*

After selecting the best vehicle type for the cargo company, it was decided to choose the shelf type for the selected vehicle type for using more effective the vehicles` storage capacity, reduce the time loss during loading and unloading.

AHP has implemented three alternatives and three criteria for select the most suitable shelf type for the vehicle. The results are presented in Table 4.

According to AHP results, Steel Shelving for Higher Roof Van is the best alternative shelf type for the selected vehicle. Aluminum Shelving for Higher Roof Vans has the second-best weight and Pull Out Shelving for Higher Roof Vans has the last suitable shelf type according to the results. With this selected shelf type, vehicles` storage capacity can be used more efficiently while reducing the damage and time.

**Table 4.** AHP Results for selecting suitable shelf type

| Alternatives | Scores |
|---|---|
| **Steel Shelving for Higher Roof Vans** | **0.5425** |
| Aluminum Shelving for Higher Roof Vans | 0.3501 |
| Pull Out Shelving for Higher Roof Vans | 0.1048 |

## 4 Conclusion

In this study, it`s aimed to find alternative solutions for the distribution problems of one of the cargo companies in Turkey. The observations are done in Adana branches of the company and two main problems are detected. These are the absence of an intra-vehicle design, and unsatisfying and expensive shuttle bus routing.

One of the problems is that the company does not have a certain intra-vehicle storage design. The absence of intra-vehicle design causes employees` time losses and package damages which is also reflects as customer dissatisfaction. To solve this problem, firstly appropriate vehicle is chosen from four alternatives by AHP and TOPSIS methods. According to capacity, price, suspension softness and fuel usage criteria, the Mercedes Sprinter Panelvan is selected as the most appropriate vehicle for the company. Then, the appropriate intra-vehicle shelving system for the chosen vehicle is selected from three alternatives by using the AHP method. According to price, space usage and durability criteria, it is indicated that the steel shelving system is the most convenient intra-vehicle design for the company.

The company`s other problem is determined as the shuttle busses which are sent from the transfer center to branches to collect the packages, which will be transported, create significant expenses to the company. These expenses are aimed to be reduced in this study by decreasing the number of vehicles and creating the shortest and the most effective route for the vehicles. This problem is named as vehicle routing problem (VRP) which is one of the most important topics in the logistics industry.

VRP is used to find an optimal solution for the routes of the vehicle fleets which are transporting goods from a depot to branches with predetermined demands. Various constraints are formed to solve the problem; such as vehicle capacity, starting/ending nodes, and several vehicles. The goal is determined to find the minimum cost for an alternative route of four shuttle buses. The General Algebraic Modeling System (GAMS), which is a high-level modeling system, is used to find an optimal solution for this mathematical problem.

According to the GAMS solutions, the daily fuel cost of the suggested vehicle fleet is reduced to 136.76 ₺ from 162.8 ₺, which is 16% lower from the current fuel cost. The suggested model indicates more efficient vehicle capacity usage, less vehicle amount and effective routes than the current situation. Also, by reducing the number of shuttle busses, the company may cut some additional costs such as maintenance of vehicles, salaries of employees, etc

**Conflict of interest**

The authors declare that there is no conflict of interest.

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The similarity rate of the article should be declared here.

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