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# Analytic Network Process in Location Selection and Its Application to a Real Life Problem

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***Abstract*—**Location selection presents a crucial decision problem in today's business world where strategic decision making processes have critical importance. Thus, location selection has strategic importance for companies in boosting their strength regarding competition, increasing corporate performances and efficiency in addition to lowering production and transportation costs. A right choice in location selection has a direct impact on companies' commercial success. In this study, a store location selection problem of Carglass Turkey which operates in vehicle glass branch is handled. As this problem includes both tangible and intangible criteria, Analytic Network Process (ANP) was accepted as the main methodology. The model consists of control hierarchy and BOCR subnetworks which include clusters of actors, alternatives and criteria. In accordance with the management's choices, five different locations were selected. In addition to the literature review, a strict cooperation with the actor group was ensured and maintained while determining the criteria and during whole process. Obtained results were presented to the management as a report and its feasibility was confirmed accordingly.

***Keywords*—**Analytic Network Process, BOCR, location selection, multi-actor decision making, multi-criteria decision making, real life problem.

## I. Introduction

In recent years, while companies rapidly broaden their scope of operations with additional branches, location selection problem appears as a strategic multi-criteria decision problem, which has a direct impact on competitiveness and overall performance [1]. Whereas a determined location force the organization to operate in a particular location, a potential mistake in this selection may cause such disadvantages as increased transportation costs, loss of qualified labor force and adversely affected administrative processes [2]. Therefore, a convenient location must fulfill companies' goals by optimizing their profitability and help them survive in today's highly competitive business environment [3]. In order to function in accordance with potential predetermined goals, selection of a convenient location must be handled within all its aspects. In compliance with the nature of real life problems, location selection problems have a complex structure as they include both tangible and intangible criteria with multiple alternatives. Therefore, the decision process itself has to be carried on meticulously while determining criteria and alternatives. In the literature, various methods has been applied to location selection problems, such as Analytic Hierarchy Process (AHP), ANP, Delphi, ELECTRE, PROMETHEE, TOPSIS, VIKOR including integrated approaches [4]-[13]. In this study, a real world store location selection problem of Carglass Turkey, which operates in auto glass industry, is handled. The objective of the study is to solve Carglass Turkey's store location problem by using ANP with BOCR and multi actors and obtain a viable solution.

This study consists of four sections: In the first section a brief introduction to the subject is presented. In Section II, ANP method with a brief overview to its applications in the literature is given. In Section III, the definition of location selection problem of Carglass Turkey with the ANP model, the steps of the solution process and its results were given. The evaluation of the results constitutes the last section.

## II. ANP and Its Applications

AHP, which is an earlier form of ANP and was developed by Thomas L. Saaty in 1970s, is a comprehensive framework and designed to model real-world problems that include both tangible and intangible criteria. In addition, AHP is a useful tool to model multi-objective, multi-criteria and multi-actor problems with various alternatives as it uses hierarchic structures [14], [15]. However, in real world decision problems, selection criteria can determine the importance of alternatives and vice versa [16]. Because of this dependency and interrelations among criteria and alternatives, real world decision problems may not be represented hierarchically [17]. Therefore, it can be stated that this type of functional interactions requires a network system [18]. In this context, Saaty later introduced ANP which bases on AHP [17]. ANP is more convenient to solve complex real-world problems as it groups all criteria, alternatives, actors and objectives in one framework which permits interactions and feedbacks between and within groups [16]. While AHP uses one-way hierarchic arcs to represent interrelations among clusters, the network structure of ANP connects all clusters by considering their unique mutual interactions by one-way, two-way or looped arcs [19]. A network presents a multi-directional and non-linear structure however in a hierarchy; relations are shown in a linear structure where upper level clusters have dominance over lower clusters [20]. ANP also allows performing with a subdivision which facilitates the modelling of the decision problem by constituting a higher level network and a control network which includes four sub networks namely, Benefits, Opportunities, Costs and Risks (BOCR) [21]. ANP has a wide range of applications in the literature because of its easy-to-

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use structure which allows representing interactions between criteria, alternatives and actors in complex real life decision problems. In Table I, an overview of ANP applications in the literature is given.

TABLE I
AN OVERVIEW TO APPLICATIONS OF ANP

| Application Areas | Articles |
|---|---|
| Location Selection | [22]-[27], [8] |
| Project Selection | [28]-[30] |
| Urban transformation, housing, environment, waste systems | [21], [31]-[33] |
| Market share estimations | [34], [35] |
| Information Technologies | [20], [14], [36] |
| Supplier Selection | [37]-[41] |
| Resource planning, staff, business partner selection | [41]-[44] |

As it can be seen in Table I, ANP has been applied in several decision problems such as location, project, partner and supplier selections, urban studies, information technologies etc.

## III. AN APPLICATION OF ANP IN STORE LOCATION SELECTION

Belron Inc. is one of the leading companies in vehicle glass repair and serving more than 8 million customers in 34 countries with several brands, such as Carglass Europe, O'Brien Australia, Safelite USA, Apple Auto Glass and Speedy Auto Glass Canada. Belron operates in Turkey via Carglass Turkey, serving more than 110.000 clients a year with 7 branches and 212 stores. Recently, company faced a location selection problem after deciding to open a new store in one of Turkey's top three metropolitan cities. As mentioned earlier, location selection problems present complex structures because they include both tangible and intangible criteria with multiple alternatives and actors. Therefore, a preliminary meeting has been organized with participation of the management. In this meeting, brief information regarding ANP is given. In addition, the importance of a strict collaboration and interaction during the solution process has been explained. As a result, ANP has been offered and accepted as the methodology in this study. The solution steps include definition of the problem, establishing the model, obtaining data by pairwise comparisons, determining the weights of criteria and importance values of alternatives and in conclusion interpretation of the results and implementation. These steps were explained respectively.

### *A. Definition of the Problem*

Along with the improving market share, the management of Carglass Turkey decided to open a new store to meet the increasing demand and reach their growth target for this year. After defining the decision problem, first interview was held with the general manager (GM) in order to obtain information concerning managerial processes and determine actors accordingly. It was mentioned that, although final decisions were made by the GM, related departments managers are also involved in the decision processes. Therefore, in this decision problem, five actors were defined as operations manager (OM), supply chain manager (SCM), finance manager (FM), marketing manager (MM) and the GM. As a strategic decision problem which affects companies' competitiveness, related literature was reviewed and as a result over 30 criteria were presented to the actor group. These criteria were narrowed to 25 and grouped within the BOCR network. The distribution of the criteria in BOCR subnetworks is given in Table II.

TABLE II
CRITERIA DISTRIBUTION IN SUBNETWORKS

| Benefits (B) | Opportunities (O) |
|---|---|
| Nearness to the warehouse (NW) | Availability of Carglass branch (AB) |
| Ease of inspection (EI) | Vehicle glass sales amount (GSA) |
| Nearness to market (NM) | Regional branch performances (BP) |
| Ease of access (EA) | Regional commercial activity (CA) |
| High urbanization rates (HUR) | Number of cars in the region (NC) |
| Favorable climatic conditions (FCC) | Labor supply (LS) |
| Financial advantages (FA) | Regional automobile insurance rate (AIR) |
| **Costs (C)** | **Risks (R)** |
| Construction costs (CC) | Security (S) |
| Land costs (LC) | Infrastructure (I) |
| Labor costs (LabC) | Risks related to customer potential (RCP) |
| Transportation Costs (TC) | Risks related to geographic conditions (RGC) |
| Other investment costs (IC) | Availability of rival firms (ARF) |
| | Other risks related to the market (ORM) |

According to Table II, Benefits and Opportunities subnetworks include seven criteria, while Costs have five and Risks include six. In the first meeting with the actor group, this distribution was confirmed and in addition, five location alternatives were also determined and named as L1, L2, L3, L4 and L5 in compliance with Carglass Turkey's confidentiality policy.

### *B. Establishing the Model*

In this step, the decision problem was constituted as a network model. In accordance with the interaction and feedback context of ANP and company's operational processes, connections with regard to dependencies were made between criteria and actors. The network model consists of a control hierarchy and BOCR subnetworks. The first part is shown in Fig. 1.

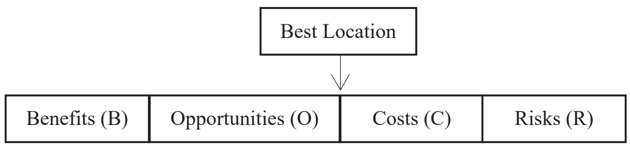


Fig. 1 The control hierarchy of the location selection problem

As it can be seen in Fig. 1, the control hierarchy includes the objective and BOCR structure. In continuation, BOCR subnetworks were modelled. Benefits (B) subnetwork can be seen in Fig. 2.

According to Fig. 2, there are three clusters, namely alternatives, criteria and actors in this subnetwork. Both one-way and two-way dependencies are included. There are two-way interactions between all alternatives and the criteria. Concerning criteria and actors; every actor except the GM are linked to the related criteria which they are responsible in regular business operations. As the final decision maker, GM has linked to every criterion in the cluster. Accordingly, Opportunities (O) subnetwork is shown in Fig. 3.

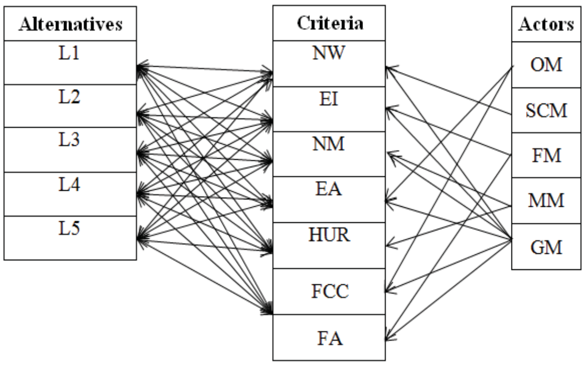


Fig. 2 Benefits subnetwork

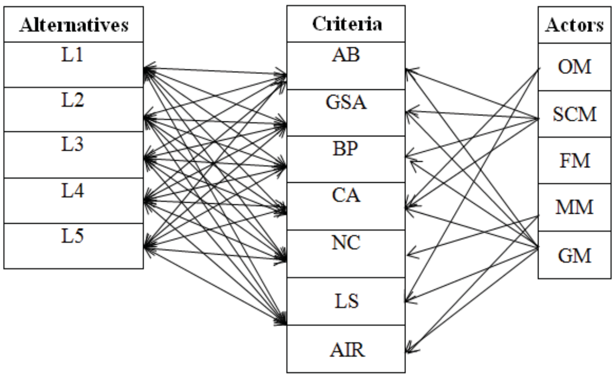


Fig. 3 Opportunities subnetwork

Similar to Benefits, two-way dependencies are seen between alternatives and criteria clusters. Regarding criteria and actors' clusters, finance manager (FM) has no connection with any of the criteria; which means, FM has no operational responsibility concerning these factors. Costs (C) network is shown in Fig. 4.

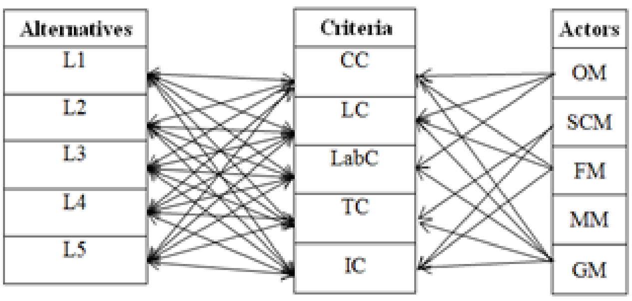


Fig. 4 Costs subnetwork

As it can be seen in Fig. 4, there are both one-way and two-way dependencies in this subnetwork. While alternatives and criteria have the same interaction as previous subnetworks; in this subnetwork, marketing manager (MM) has no connections with any of the criteria. Finally, Risks (R) subnetwork was constituted and given in Fig. 5.

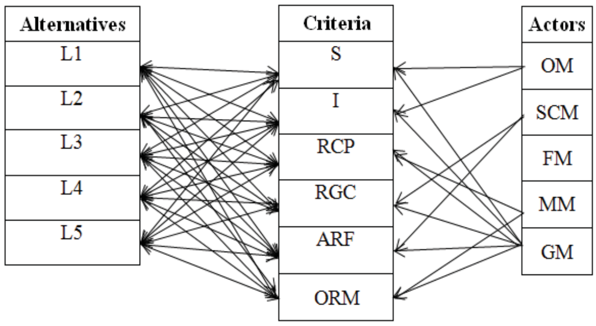


Fig. 5 Risks subnetwork

In accordance with other subnetworks, dependencies have the same pattern. Similar to Opportunities subnetwork, finance manager (FM) has no connection with any of the criteria.

### C. Obtaining the Data by Pairwise Comparisons

In this step, the data were collected by pairwise comparisons considering the connections that were given in subnetwork models. Similar to AHP, comparisons were performed according to 1-9 relative importance scale which is offered by [16]. At the beginning of the process, questionnaire forms were prepared for each actor. Afterwards, all actors were informed regarding the scale and pairwise comparisons. As previously mentioned, actors compared the criteria related with their profession except the GM. Questionnaires were performed as one-to-one interviews. Thereby, all data were collected and in total, 62 pairwise comparison matrices were obtained. An example of a comparison matrix which is performed with the GM concerning the cost criteria is given as follows in Table III:

TABLE III
PAIRWISE COMPARISON MATRIX FOR COSTS SUBNETWORK

| | CC | LC | LabC | TC | IC |
|---|---|---|---|---|---|
| CC | 1 | 2 | 1/3 | 1/4 | 1/3 |
| LC | - | 1 | 1/4 | 1/3 | 1/3 |
| LabC | - | - | 1 | 1/3 | 3 |
| TC | - | - | - | 1 | 3 |
| IC | - | - | - | - | 1 |

According to Table III, *Labor Costs (LabC)* criteria has moderate importance over *Land Costs (LC)* criteria; whereas *Transportation Costs (TC)* criteria has moderate plus importance over *Labor Costs (LabC)* criteria. While *Construction Costs (CC)* criteria has weak importance over *Land Costs (LC)* criteria, *Other Investment Costs (IC)* criteria has a moderate importance over *Construction Costs (CC)* criteria. In continuation, all pairwise comparisons were performed similar to the given example.

According to the ANP analysis, as a result of comparing $n$ component with each other, an $nXn$ dimension matrix is obtained. However, there may occur inconsistencies during these comparisons. Thereby, a consistency index ($CI$) and a consistency ratio ($CR$) must be calculated. If $n$ is the number of criteria and $\lambda_{max}$ is the largest or principal eigenvalue of given pairwise matrix, the consistency index will be:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

thereby, *CR* is formulated as:

$$CR = \frac{CI}{RI} \quad (2)$$

*RI,* namely random consistency index, provides a value with regard to number of criteria (*n*) [14], [16]. If *CR* is less or equal to 0.10; then the matrix is considered to be consistent, while some scholars offer that this value can be up to 0.20 [15]. Super Decisions software, which is developed for ANP applications, is used for all analysis. As a result of all pairwise comparisons, *CR* values were less or equal to 0.10, hence all of them accepted as consistent.

### *D.Determining the Weights of Criteria and Importance Values of Alternatives*

Since all BOCR components have equal importance for the management, the final relative importance weights of all criteria in BOCR subnetworks were obtained via Super Decisions software and given in Table IV. According to Table IV, *Nearness to Market* (*NM*) criteria is the most important criteria compared to others in benefits subnetwork. *Regional Automobile Insurance Rate* (*AIR*) criteria has superiority over other criteria in opportunities subnetwork. While *Transportation Costs* (*TC*) criteria has a significant importance than other criteria in costs subnetwork; similar situation can be seen in risks subnetwork for *Risks Related to Customer Potential* criteria (*RCP*).

In the next phase of the analysis, relative importance values of alternatives were calculated based on two formulas, namely the additive and multiplicative. In the additive approach, the sum of components which are considered to have negative influences (*Costs* and *Risks*) are subtracted from the sum of components which are considered to have positive influences (*Benefits* and *Opportunities*). The formulas are given below, where *B*, *O*, *C* and *R* represents the synthesized results; *b*, *o*, *c* and *r* are the importance rate of these components and by normalized values of 1/*C* and 1/*R*, the conversion of the negative influences of *Costs* and *Risks* components to positive is aimed [14]:

$$bB + oO - cC - rR \quad (3)$$

$$B^b\, O^o\, [(1/C)_{\text{Normalized}}]^c\, [(1/R)_{\text{Normalized}}]^r \quad (4)$$

The calculation in (3) provides the best alternative, considering short-term affects, whereas long-term effects are considered through (4) [45]. These calculations are supported by Super Decisions software as well.

In conclusion, the final relative importance values of the alternatives were calculated based on these formulas and given in Table V.

### *E. Interpretation of the Results and Implementation*

In the last phase, obtained results were evaluated. According to Table V, the fifth alternative, L5, is the best alternative with regard to additive formula. Therefore, it can be stated that, this option is situated in the most advantageous location considering all criteria and short-term effects. However, L2, the second alternative has the highest importance value among other alternatives according to the multiplicative formula. As an interpretation, this result indicates that this location has superiority when long-term effects are considered. In compliance with Carglass Turkey's long-term goals and the importance of the decision problem itself, L2 alternative has been suggested as the best alternative for a store location. In the last meeting with Carglass Turkey management, these obtained results and interpretations were presented to the management as a report and its feasibility were confirmed by actors, hence the management accordingly.

## IV. CONCLUSIONS

Location selection is a strategic decision problem for companies in today's competitive business environment. By making an accurate decision, more efficient, advantageous and profitable returns are obtainable. Therefore, this decision must be made by considering long-term effects. As a complex problem which includes multiple alternatives and both tangible and intangible criteria, it is essential to choose an appropriate method for the solution. In the literature, several methods and integrated approaches have been applied to location selection problems such as AHP, ANP, ELECTRE, PROMETHEE, TOPSIS, etc.

TABLE IV
FINAL RELATIVE WEIGHTS OF CRITERIA IN BOCR SUBNETWORKS

| | Criteria | Final Relative Weights | | Criteria | Final Relative Weights |
|---|---|---|---|---|---|
| **B** | NW | 0.10659 | **O** | AB | 0.07446 |
| | EI | 0.0239 | | GSA | 0.28444 |
| | **NM** | **0.32113** | | BP | 0.1639 |
| | EA | 0.26794 | | CA | 0.04204 |
| | HUR | 0.18374 | | NC | 0.09774 |
| | FCC | 0.06354 | | LS | 0.03492 |
| | FA | 0.03317 | | **AIR** | **0.30037** |
| | **Criteria** | **Final Relative Weights** | | **Criteria** | **Final Relative Weights** |
| **C** | CC | 0.08784 | **R** | S | 0.08643 |
| | LC | 0.06919 | | I | 0.05147 |
| | LabC | 0.26474 | | **RCP** | **0.42568** |
| | **TC** | **0.41857** | | RGC | 0.03637 |
| | IC | 0.15966 | | ARF | 0.14304 |
| | | | | ORM | 0.25702 |

TABLE V
FINAL IMPORTANCE VALUES OF ALTERNATIVES

| Alternatives | B | O | C | R | 1/C | $N_{1/C}$ | 1/R | $N_{1/R}$ | Additive | Multiplicative |
|---|---|---|---|---|---|---|---|---|---|---|
| **L1** | 0,2514 | 0,214285 | 0,295245 | 0,193292 | 3,387017562 | 0,12 | 5,173519856 | 0,176756162 | -0,005713 | 0,182006991 |
| **L2** | 0,280267 | 0,236831 | 0,254165 | 0,086809 | 3,934452029 | 0,13 | 11,5195429 | 0,393571543 | 0,044031 | **0,243181437** |
| **L3** | 0,136776 | 0,1586 | 0,092668 | 0,231632 | 10,79121164 | 0,37 | 4,317192789 | 0,147499275 | -0,007231 | 0,185137374 |
| **L4** | 0,187013 | 0,204201 | 0,161982 | 0,222183 | 6,173525453 | 0,21 | 4,50079439 | 0,153772125 | 0,00176225 | 0,187407055 |
| **L5** | 0,515737 | 0,186083 | 0,19594 | 0,266085 | 5,103603144 | 0,17 | 3,758197568 | 0,128400895 | **0,05994875** | 0,215077901 |
| **Total** | | | | | 29,38980983 | 1,00 | 29,26924751 | 1,00 | | |

In this study, Carglass Turkey's store location selection problem is handled. As a convenient approach to real life multi-criteria problems, which includes interactions and feedbacks among criteria and alternatives, ANP method has been used to solve this problem. The proposed model consists of two parts, (i) control hierarchy and (ii) BOCR subnetworks with clusters that include actors, criteria and alternatives with one-way and two-way connections between these elements. BOCR subnetworks included same five actors for each cluster, namely operations, supply chain, finance, marketing and general manager. There were seven criteria for benefits, seven criteria for opportunities, five for costs and six criteria for risks in order to evaluate five location alternatives. In the next phase, pairwise comparisons were performed with each actor in one-to-one interviews and Saaty's [16] 1-9 scale has been used for these comparisons. All comparisons were turned out to be consistent; therefore, weights of all criteria, given in Table IV are obtained. According to the results, *Transportation Costs* criteria (0.48) under costs subnetwork emerged to be the most important criteria among all others in all subnetworks. This is followed by the *Risks Related to Customer Potential* criteria (0.46) under risks subnetwork, *Nearness to Market* criteria (0.365) under benefits subnetwork and *Regional Automobile Insurance Rate* criteria (0.303) under opportunities subnetwork respectively.

In the last phase of the analysis, final importance values of the alternatives were obtained via additional and multiplicative formulas. According to the results, L5 alternative appeared as the best alternative considering additive formula, namely, short-term effects. The second best alternative was L2. However, as a crucial decision, location selection supposed to take long-term effects into consideration. Therefore, after application of the multiplicative formula, the best alternative was determined as L2. The related calculations were made through Super Decisions software and a report which includes all results and interpretations was presented to the management and its feasibility was confirmed.

In conclusion, the limitation of this study is that it was performed in a particular industry, therefore the criteria were determined in accordance with this business line. However, as both established network model and obtained results presented feasible results, this study may provide an example and insight to researchers, decision-makers and executives who will face a similar problem in the future.

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