An Integrated Approach for ATM Location Strategy Using Analytic Network Process and Weighted Goal Programming

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Abstract: - Automatic Teller Machines (ATMs) are still one of the most important channels to enhance market penetration for banks and location selection decision has a substantial effect on long-term profitability and sustainability. Therefore, nowadays ATM location problem is a popular topic in ATM management. This paper proposes a new practical methodology, which combines Analytic Network Process (ANP) and Goal Programming (GP) model for a real case study. We apply this methodology to the actual data of a Turkish bank to demonstrate the applicability and validity of the model. The model simultaneously determines the total number of required ATMs and locations of ATMs to meet the customers' demand. We illustrate behaviour of the model under different scenarios to provide useful insights into the decision process. The results of the model are found satisfactory; furthermore, trade-off ability as well as simplicity of the model is appreciated by the bank management.

Key-Words: - Banking Industry, Decision support systems, Goal programming, Location selection

1 Introduction

Reducing capital and operational costs became a main course of action to improve business performance and to be competitive for every company in today's challenging economy. However, companies also aim to improve their service delivery and customer satisfaction accordingly. Location management is widely regarded as one of the critical issues for its cost reduction potential in every line of business. Therefore, companies need to develop location strategies for their business units such as factories, distribution centers and stores in accordance with the overall business strategy.

In general, facility location problem can be defined as locating facilities in such a way that the total cost of keeping these facilities operational and satisfying customer demand is minimized for a given a set of possible facility locations and a set of customer locations to serve [1]. Placing facilities is a result of long-term operational and logistical decisions, which are associated with high costs due to property acquisition and facility construction. Thus firms are expected to plan facilities remain profitable in the same location for a long period of time by considering changing conditions of the current system [2].

Selecting Automatic Teller Machines (ATMs) locations is a vital decision for banks for making service available to their customers when they need it and due to the opportunity of cost optimization. Different locations of ATMs usually result in different returns and therefore it is essential to decide the right place for ATM deployment. ATMs are not only located outside of the branch lobbies and started to appear in new places including gas stations, supermarkets, and drugstores. The ATM channel is still preserving its key role since 1960s as a core banking touch point for customers by providing access to funds and banking experience. Importance of its role has not been diminished even in the evolvement of new electronic payment systems. Furthermore, branch network optimization causes a decrease in the number of branches and this reduction strengthens the ATMs prominence as customers sustain their need for physical contact with banks. According to the Consultative Group to Assist the Poor's analysis, ATM transaction costs in high-traffic locations can be advantageous by as much as 90% percent compared to branch transaction costs. Moreover, as the cost of establishing wide branch networks rises, particularly in rural locations, ATMs can act as a "mini branch" where customers conduct various transactions, which they could in bank branches [3].

Customers' ATM habits have changed over time due to increasing ATM fees and usage of debit and credit cards. Some customers began to limit their usage with their own financial institutions' ATMs where they would not be charged. Others started to use ATMs less often by withdrawing more money each time. As transaction volume per ATM has been on the decline because of consumer habits and growing number of ATMs, the ATM deployment strategy became more critical [4]. Nonetheless, the number of installed ATM machines in the world is still increasing. It was projected to be 4.0 million by the end of 2018 where it was 2.0 million in 2010 and 3.2 million in 2014 [3]. Therefore, banks have started to pay more attention to ATM location management.

This paper proposes a novel integrated approach that combines Analytic Network Process (ANP) and Weighted Goal Programming (WGP) to determine the satisfactory locations for ATM deployment problem. The foundation of the problem is built on a case where a bank needs to evaluate its existing ATM locations and the effectiveness of the methodology is demonstrated with this real case study. However, the model can be also applied to the problem where the bank is at the initial stage of locating its ATMs.

The remainder of the paper is organized as follows: initially brief literature review of the location problems is presented, and then the proposed methodology, the utilized techniques, application of the methodology with the results are introduced respectively, and finally concluding remarks are highlighted.

The main objective of the paper is aiding researchers as well as decision makers such as bank managers, consultants and banking software developers who work on ATM location management to make feasible location decisions. Our proposed methodology differentiates from the previous ATM location studies in three perspectives, which make the methodology more applicable to real-life problems. Initially, unlike the previous researches the new approach considers multi-criteria nature and discerns the resource limitations of the problem. Second, it takes account of the locations' attractiveness from decision makers' point of view. Lastly, the methodology uses two operations research techniques to obtain complete solutions in a simpler and more efficient way.

2 Literature Review

2.1 General Overview

In the literature, there exist some studies that focus on bank branches or ATMs and adopt single criterion decision making. These studies employed solely heuristics or combines heuristics with exact algorithms.

Li et al (2009) developed a model for ATM location selection problem, which employed Particle Swarm Optimization (PSO) algorithm and Geographic Information System (GIS) [5]. Aldajani and Alfares (2009) introduced a mathematical model and used a novel heuristic algorithm based on the two-dimensional convolution to find the optimum number and locations of ATMs that satisfy service level coverage requirements [6]. Qadrei and Habib (2009) formulated the ATM deployment problem as an optimization problem and developed a Genetic Algorithm (GA) to search good solutions [7].

Alhaffa et al. (2011) presented a Rank Based Genetic Algorithm using convolution (RGAC) for ATMs location problem [8]. Their study is the only one, which considers different types of ATMs and the maximum number of ATMs to be deployed per location in our knowledge. Zhang and Rushton (2008) introduced a multi-site location-allocation model, which is described in the context of locating bank branches. They aimed to assist multi-site facility owner for locating new sites or closing current sites in the presence of one or more competitors and suggested GA for solving the model [9].

In most real world problems, making decisions that are only based on one criterion is insufficient; probably there is a need to consider several conflicting criteria. When decision maker is dealing with multiple and conflicting criteria, Multi-criteria Decision Making (MCDM) is used for finding compromise solutions. MCDM methods are not fully automated that yield the same solution for every decision maker (DM) as the DM provides subjective information, however, the design of mathematical and computational tools is considered to support the DM to lead a solution. These methods have been utilized to decide a preferred alternative, classify the alternatives in a number of categories, and/or rank the alternatives in a preference order. They are sometimes also used to allocate scarce resources to the alternatives based on the results of the analysis.

2.1 MCDM in Location Selection Literature

MCDM methods are utilized in many location problems, which take multi-criteria nature of the problem into consideration. Badri (1999) integrated Analytic Hierarchy Process (AHP) and multi-objective goal-programming (GP) methodology for global facility location-allocation decisions [10]. Jayaraman (1999) suggested a multi-objective logistics model for finding locations of a given number of capacitated service facilities [11]. Min and Melachrinoudis (2001) developed an analytical model based on a chance-constrained goal program to evaluate bank location strategies under dynamically changing scenarios [12]. Stummer et al. (2004) proposed a two-phase solution procedure that applied multi-objective tabu search and clustering to determine the size and location of medical departments in a hospital network [13].

Villegas et al. (2006) solved a bi-objective uncapacitated facility location problem (BOUFLP) to design a Colombian coffee supply network [14]. They developed three different algorithms based on the Non-dominated Sorting GA, Pareto Archive Evolution Strategy, and mathematical programming for the BOUFLP. Araz et al. (2007) examined multi-objective covering-based emergency vehicle location model where they employed lexicographic linear programming and fuzzy GP [15]. Chu et al. (2010) investigated fuzzy chance-constrained programming model for a multi-echelon reverse logistics network for household appliances and used hybrid genetic algorithm to generate low cost [16].

Chen and Cheng (2011) addressed multi-objective service facility location problems with dynamic demands by using multi-objective GA [17]. Ho et al (2013) analyzed the location selection problem for buying and renting coffee shops and restaurants. They combined AHP and multi-choice goal programming (MCGP) as a decision tool to obtain appropriate location from many alternatives [18]. Rahmati et al (2014) investigated ATM and vendor machines problem as a bi-objective model where stochastic demand within the M/M/1/K queue system is considered. Moreover, they employed two popular multi-objective evolutionary algorithms to produce efficient solutions [19].

Beheshtifar and Alimoahmmadi (2015) integrated GIS analysis with a multi-objective GA to solve location allocation problem for healthcare facilities. They employed TOPSIS (Technique for Order Preference by Similarity to an Ideal Solution) as a posteriori preference method to assess and compare Pareto optimal solutions [20]. Zografidou et al. (2016) searched for the optimal design of the renewable energy production network. They applied weighted GP model to select the locations and data envelopment analysis (DEA) approach to filter out the best possible network structure by reducing the solutions [21].

It is apparent that the concentration on ATM location problems is substantially lower than the other location problems. There are several factors that affect ATM location decision and these factors should be analyzed in detail in order to make sound decisions. Additionally, the preferences of the decision makers should also be considered in the problem since neglecting the judgments and the preferences of the DMs would end up with the impracticable solutions. Moreover, there is an inevitable necessity to consider resource limitations while developing deployment strategy for ATMs. Even, the previous studies cover valuable information for ATM location management practitioners, to the best of our knowledge; there are no previous ATM location studies that comprise all of these issues. Therefore, we propose a novel solution method, which can be followed up to fill this gap in the literature.

Analytic Network Process (ANP) is regarded as the most appropriate technique to evaluate the importance of ATM location selection factors, which have interdependencies between. ANP is a widely used technique that is grounded in pairwise comparisons. Moreover, goal programming (GP) optimization technique is found applicable as it considers multiple conflicting goals, enables the decision maker to choose from an infinite number of alternatives and has the potential to solve large-scale problems. Heuristic approaches could also be applicable to ATM deployment problem; however, GP is a less complicated method then heuristics for practitioners in the industry due to its simplicity of modeling and programming.

3 Proposed Methodology

Banks invest in the ATM network and select ATMs locations to satisfy their existing customers and also to gain the potential customers. The number of ATMs and their accessibility became a part of competitive strategy for the banks as well as low transaction fees. However, locating ATMs still do not get the attention that it deserves. Traditionally, most of the banks make the ATM location decision based on some figures that DM thinks they are important and DM's past experience. Ultimately, the decision is made instinctively and it is not possible to conclude if the location is actually the best decision. Moreover, a wrong positioned ATM would cause customer loss and the cost of ATM repositioning. Therefore, there is a need for an analytical approach in the area of ATM management for location selection.

In this paper, we propose a hybrid approach for ATM location selection problem that applies to

Analytic Network Process (ANP) and weighted goal programming (WGP) to make sound location decisions. The decision process addresses the problem of determining the number and locations of ATMs and can be divided into five major phases. Briefly, in the first phase as a result of the interviews and literature surveys conducted, the location factors are identified. Pairwise comparisons are carried out and weights of location factors are obtained with the use of ANP in the second phase. Third phase uses the weights of location factors as an input in the calculation of the scores for subregions. In the fourth phase, WGP model constructed, which considers scores of subregions as one of its goals, for location selection and location decision is made in consequence of evaluating different location alternatives with scenario analyses. The selected scenario is visualized in Google Maps in the last phase. The proposed methodology is presented in Appendix.

3.1 Phase 1 Defining the problem

In the first phase of the process, a series of interviews were conducted with experts from different banks, who have deep knowledge and experience in banking sector, to define the ATM location problem. It is noticed that there is a need for a systematic method to make location decisions. As a result of interviews, the problem was defined as deciding where to deploy new ATMs and which of the existing ATMs should maintain their positions or which of them were not located properly, hence should be removed.

There are quantitative and qualitative factors that are needed to be considered simultaneously while making the ATM location decision. Understanding the fundamental factors, which we call location factors (LFs), that affect location selection is critical to achieve sound decisions. In order to comprehend these factors; literature survey was carried out on service facilities. Additionally, the LFs that were mentioned by the experts during the interviews were also taken into account in the problem. Then, LFs were categorized into five groups based on their characteristics as seen in Table1.

3.2 Phase 2: Determining the importance of location factors

The study employed Analytic Network Process (ANP) to determine the importance of location factors that lead the ATM location decision. ANP was proposed by Saaty (1996), as a generalization of AHP, which can handle the dependencies and where the decision problem can be structured as a network of criteria and alternatives grouped into clusters [22]. The elements in the network can have relationship in any direction, such as; feedback and complex inter-relationships within and between clusters. In ANP model, hierarchy is not required and the levels of AHP model are replaced with the clusters that consist of nodes or elements.

ATM location selection decision requires considering several conflicting criteria that have interrelations among them. In order to apply ANP, the interaction (inner and outer dependencies) between the factors was determined and network structure was constructed based on the interactions. Pairwise comparison matrices were built and a group of experts, who work in ATM management departments in different banks, used these matrices to evaluate the factors in linguistic terms and SuperDecisions® is preferred to perform ANP computations. The network structure is provided in Fig.2. and the ranking and weight of each LF are presented in Fig.3.

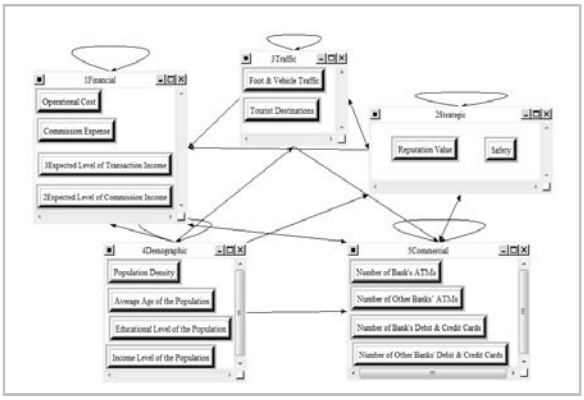


Fig.2. ANP Network Structure

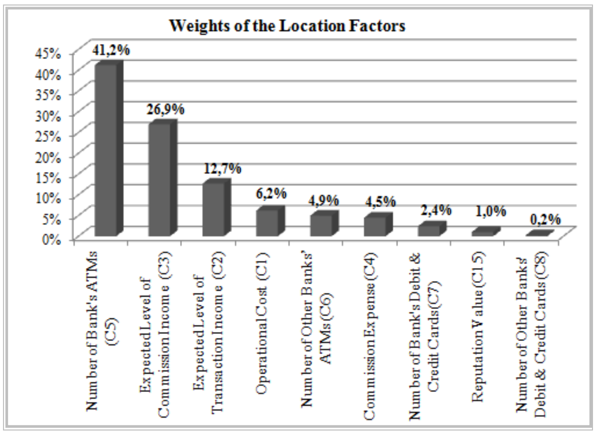


Fig.3. Weights of Location Factors

A decision group in a Turkish bank, that is ranked in the top 10 according to the size of assets and number of ATMs where there are 47 banks in Turkey, performed the following steps of the application. This decision group comprises experts who have different responsibilities on ATM management. The decision group also validated the list of location factors, which is given in Table 1.

Table 1. Factors analyzed in the ATM location selection problem

Category	LF Code	LF Definition
Financial	C1	Operational Cost
	C2	Level of Transaction Income
	C3	Expected Level of Commission Income
	C4	Commission Expense
Commercial	C5	Number of Bank's ATMs
	C6	Number of Other Bank's ATMs
	C7	Number of Bank's Debit and Credit Cards
	C8	Number of Other Bank's Debit and Credit Cards
Traffic	C9	Foot and Vehicle Traffic
	C10	Tourist Destinations
Demographic	C11	Population Density
	C12	Average Age of the Population
	C13	Educational Level of the Population
	C14	Income Level of the Population
Strategic	C15	Reputation Value
	C16	Safety

3.3. Phase 3: Calculating scores of subregions

The decision group performed long discussions on selection of application region and subregions. Besiktas is a municipality of Istanbul, which is located on the European side of the city, was chosen as the application region due to its strategic position. The population is 186,570 and the area is 21.33 km^2. Besiktas has a role as the entrance of the Bosphorus Bridge on the European side and it is the feeder for the inner-city motorway on the bridge. Moreover, it hosts one of the most important public transportation hubs and several touristic places. Therefore, thousands of people commute every day to or via Besiktas.

Besiktas has 23 districts and four districts were selected as sub regions for the implementation of the methodology. There are 6 ATMs of the bank where 59 ATMs of competitors located in these four districts. Annual transaction data of all districts with the coordinates of ATMs were gathered and analyzed for score computation and location selection. Score was used as an indicator to measure the attractiveness of each district for the bank. The attractiveness was calculated by considering six LFs which we found the most important for location selection and constitute 96.39% of the weight of all factors.

All the factors except "Number of Bank's ATMs" have a positive effect on attractiveness of the location since the eagerness of the bank to locate ATMs would be inversely proportional to the number of bank's own ATMs. Collected data for 23 districts was sorted in ascending order based on each LF. Then, frequency distribution was used for grouping the data. Score was assigned in five-point scale for each data group by the decision group according to the factor's positive or negative effect on attractiveness of the location.

Table 2 shows the number of other banks' ATMs (C6) for each of the four districts. District1 has the minimum number of ATMs where District2 has the highest number of ATMs. Assigned scores, on a scale ranging from 1 to 5, for location factor C6 based on the frequency distribution are depicted in Table 3.

Table 2. (C6) in each District

Number of Other Banks' (C6)	Score
0-13	1
14-27	2
28-41	3
42-55	4
56-69	5

The district that has other banks' ATMs in the range of 0-13 was given the score of "1", whilst the district that has other banks' ATM in the range of 56-69 was given the score of "5". Therefore, District1 was assigned score "1" as it has 6 ATMs and District2 was assigned score "2" as it has 25 ATMs. Consequently, the higher score denotes the stronger eagerness of the bank to locate ATMs in the related districts.

The formulation of weighted total score calculation for each district is given as follow:

$$S_t = \sum_{f \in F} w_f s_{ft} \ \forall t \in T, \quad (1)$$

Indices & Sets:

f **:** index for location factor,
t **:** index for district,
F **:** finite set of indices associated with LFs,
T **:** finite set of indices associated with districts,

Parameters:

w_f **:** the weight of location factor $f, \forall f \in F$,

s_{ft} **:** the score of district t according to the location factor f

s_t **:** total score of district t, $\forall t \in T$,

Table 3. Scores of (C6)

Number of Other Banks' (C6)	Score
0-13	1
14-27	2
28-41	3
42-55	4
56-69	5

We calculated the weighted total score (WTS) for each district based on the decision group's score and weights of LFs obtained from ANP. The score, weighted score and weighted total score of each district is provided in Table 4.

Table 4. Scores of Districts

Score							
Districts/LFs	**C5**	**C3**	**C2**	**C1**	**C6**	**C4**	
District1	3	1	1	4	1	1	
District2	2	2	3	4	2	2	
District3	1	5	5	5	1	1	
District4	5	2	3	3	2	4	
Weighted Score							
Districts/LFs	**C5**	**C3**	**C2**	**C1**	**C6**	**C4**	**WTS**
District1	1,24	0,27	0,13	0,25	0,05	0,05	**1,97**
District2	0,82	0,54	0,38	0,25	0,10	0,09	**2,18**
District3	0,41	1,35	0,63	0,31	0,05	0,05	**2,80**
District4	2,06	0,54	0,38	0,19	0,10	0,18	**3,44**

As we mentioned above, since District1 was assigned score "1" for C6 and the weight of C6 is 4.94%, the weighted score of C6 was found 0.049. The same computation was performed for each LF and district. Then, the weighted total score of each LFs based on each district was obtained by adding each LFs weighted score together.

Including weighted total score into the model strengthened the model's validity since the decision makers' experience and foresight was incorporated in the model.

3.4. Phase 4: Finding ATM locations

In ATM location problem, subjectivity should be involved in the decision process. However, making decisions only based on subjectivity would cause that the selection process is lack of accuracy and consistency. Moreover, there are multiple objectives that decision maker should take into account while developing the deployment strategy. In order to overcome these limitations, this paper integrates ANP and goal programming methodology.

Multi-objective programming (MOP) is utilized for dealing with optimization problems where several conflicting and non-commensurable objectives are needed to be considered. In MOP, the concept of optimal solution becomes meaningless since, generally, a feasible solution that simultaneously optimizes all the objectives does not exist. Therefore, MOP adopts the concept of Pareto optimality where DM deals with a large or infinite number of efficient solutions. On the other hand, DM has the chance to make tradeoffs as the improvement of one objective results in loss in another objective.

For most of the real life optimization problems, it is computationally grueling and sometimes even impossible to find all the solution points exactly. Moreover, this process is very time-consuming and hence expensive for DMs and requires excessive use of information where it is too hard to find all related and precise information. Usually, decision maker prefers to find some initial solutions to see if an exact solution is necessary. Therefore, approximation methods, which yield sufficient solutions become an attractive alternative for DMs, are frequently applied [23]. Charnes and Cooper (1957) proposed Goal Programming (GP) as an approximation method to deal with multi-objective optimization problems [24]. The main idea behind GP is to minimize the sum of deviations from the goals or aspiration levels that are determined by decision makers [25]. Goal Programming is often used to filter out the unsuitable alternatives in an efficient way when there are many alternatives [26]. GP is a robust multiple objective decision-making tool that produces a simultaneous solution to a complex system of competing objectives. In general, it can find out the following [27]:

- Input requirement to achieve a set of goals,
- Degree of attainment of defined goals,
- Optimum solution under varying input and priority structure of goals.

Weighted goal programming is applied where all the goals are in equal importance for the bank.

Weighted total score (WTS) is regarded one of the goals of the MOO model.

Goal programming model formulation for the ATM location problem is constructed as follows:

$$Minimize\ Z \equiv w_1 \frac{U_1}{G_1} + w_2 \frac{E_2}{G_2} + w_3 \frac{E_3}{G_3} \quad (2)$$

$$\sum_{j \in M} S_j Y_j + U_1 - E_1 = G_1 \quad (3)$$

$$\sum_{j \in M} Y_j + U_2 - E_2 = G_2 \quad (4)$$

$$\sum_{i \in N} \sum_{j \in M} a_i X_{ij} d_{ij} + U_3 - E_3 = G_3 \quad (5)$$

$$\sum_{j \in M} X_{ij} = 1, \ \forall i \in N, \quad (6)$$

$$X_{ij} \le Y_j, \forall i \in N, j \in M, \quad (7)$$

$$d_{ij} X_{ij} \le D, \forall i \in N, j \in M, \quad (8)$$

$$\sum_{i \in N} X_{ij} a_i \le C, \forall j \in M, \quad (9)$$

$$\sum_{j \in M} Y_j o_j \le OB \quad (10)$$

$$\sum_{j \in M_1} (1 - Y_j) v_j + \sum_{j \in M_2} Y_j u_j \le CB \quad (11)$$

$$Y_j \in \{0,1\}, \forall j \in M, \quad (12)$$

$$X_{ij} \in \{0,1\}, \forall j \in M, \forall i \in N, \quad (13)$$

The model decides the locations for ATMs and accordingly, the total number of ATMs that is required to be deployed. As a result of the model, if there is any ATM that the bank needs to remove, it is also determined. Additionally, the model assigns the demand nodes to the deployed ATMs.

The following notation is used in the model:

Indices & Sets:

i: index for demand nodes (sites of bank's ATMs and the competitors' ATMs),

j: index for potential ATM sites (sites of bank's ATMs and the competitors' ATMs),

$N = \{1,...n\}$: the set of demand nodes where demand originates,

$M_1 = \{j_1,..., j_q\}$: the set of nodes where existing ATMs are located,

$M_2 = \{j_{q+1},..., j_m\}$: the set of nodes where new ATMs can be located,

$M = \{1,..., m\} = M_1 \cup M_2$,

$q = |M_1|$: the number of existing ATMs,

$m = |M|$: the total number of existing and potential ATMs,

Parameters:

v_j : the cost of closing an existing ATM at node $j \in M_1$,

u_j : the cost of deploying a new ATM at node $j \in M_2$,

o_j : operational cost for a deployed ATM at node j ∈ M,

a_i :demand amount (transaction volume) at node i,

d_{ij} : distance between demand node i and potential ATM site j,

OB : the total annual budget available for operational expenses (opex),

CB : the total budget available for capital expenses (capex),

S_j : total weighted preference score for potential ATM site j (higher values denote higher preference and the score of related district will be assigned to each site),

C : capacity of ATM which is equal for all ATMs,

D : maximum distance that customers are allowed to travel,

w_1, w_2, w_3: weights of related deviational variable.

Decision variables:

Y_j : a binary indicator for potential ATM deployment,

$$Y_j = \begin{cases} 1, & \text{if ATM is located at node } j \in M \\ 0, & \text{otherwise} \end{cases}$$

X_{ij}: a binary indicator for demand assignment to ATM site

$$X_{ij} = \begin{cases} 1, & \text{if demand at node } i \in N \text{ is served by node } j \in M \\ 0, & \text{otherwise} \end{cases}$$

U_1, U_2, U_3: negative deviational variable associated with each goal respectively goal1, goal2, goal3

E_1, E_2, E_3: positive deviational variable associated with each goal respectively goal1, goal2, goal3.

Objective function (2) minimizes the total weighted deviations from the goals where first goal G_1 is maximization of the weighted total score of locations, second goal G_2 is minimization of total number of ATMs and third goal G_3 is minimization of total weighted travel distance of customers. Negative deviation is considered for the first goal where positive deviation is taken into consideration for the second and third goals. U_1 shows the amount that is below the target value. E_2 and E_3 show the amount which exceeds the target value. G_1, G_2 and G_3 are called aspiration levels for each goal and each constraint (3, 4, 5) restricts the deviations from these aspiration levels. Constraint (6) ensures that total demand in each node will be satisfied which means there will not be any demand node whose demand cannot be met. Constraint (7) states that demand can be only satisfied by the deployed ATMs. If an ATM is not deployed at a node, then no demand is assigned to that alternative location node. Constraint (8) limits the distance that customers will tolerate to travel and this distance is called "distance threshold". Constraint (9) indicates that satisfied demand cannot exceed the capacity of each located ATM. Therefore, total demand that is assigned to an alternative location is limited with the ATM capacity. Constraint (10) defines the total annual budget limit for operational expenses and constraint (11) guarantees that set up cost and closing cost cannot exceed the budget limit which is determined for capital expenses. If a deployed ATM is removed, the removing cost of an ATM is considered; where the deployment cost is taken into consideration if a new ATM is located. If $Y_j = 0$ for $j \in M_1$, then the existing ATM $j \in M_1$ is going to be removed with the cost of $(1 - Y_j)v_j$; if $Y_j = 1$ for $j \in M_2$, then a new ATM is going to be deployed at the potential facility site j with a cost of $Y_j u_j$ Moreover, if $Y_j = 1$ for $j \in M$, then open facility j is going to give service with cost of $Y_j o_j$. Constraints (12) and (13) are integrality constraints for the problem variables that ensure the decision variables are zero-one variables. Constraint (18) states U_1, U_2, U_3 and E_1, E_2, E_3 are non-negative continuous variables.

Percentage normalization scheme was implemented to scale all unwanted deviations where each deviation was turned into a percentage value away from its aspiration level. Different scenarios were analyzed to provide solution alternatives to the bank, so that the bank management may decide the most appropriate solution. The required resources (budget for capex and budget for opex) and distance threshold were changed to produce six scenarios, since they are the only parameters that are in control of the bank. In order to avoid DM determining the aspiration levels, the aspiration levels were set at their maximum possible values (ideal values). Ideal values were calculated by optimizing each goal individually. Thus it was ensured that each goal takes its optimal value as aspiration level based on the given scenario. We solved three single-objective optimization models for each scenario and recorded their optimal values before running the goal programming model. The controlled parameters and aspiration levels of the goals for each scenario are given in Table5.

Table 5. Controlled Parameters & Aspiration Levels for each Scenario

	Solution	**Locations that ATMs Removed**	**Locations that ATMs Deployed**
Scenario I	L3, L4, L6, L33, L37	L1, L2, L5	L33, L37
Scenario II	L1, L3, L4, L6, L33, L37	L2, L5	L33, L37
Scenario III	L1, L3, L4, L6, L33, L37	L2,L5	L33, L37
Scenario IV	L1, L3, L4, L5 L6, L7, L33	L2	L7, L33
Scenario V	L1, L3, L4, L6, L17, L19	L2, L5	L17, L19
Scenario VI	L1, L3, L4, L5,L6, L17, L19	L2	L17, L19

- Scenario I: The budget for capex is set to 350,000 TL and the budget for opex is set to 380,000 TL. Distance threshold is determined 0.6 km.
- Scenario II: The budget for capex is fixed at 350,000 TL as in Scenario I. The budget for opex is increased by 60,000 TL and assumed to be 440,000 TL, since annual operational cost of one average ATM is 60,000 TL.
- Scenario III: The budget for capex is increased to 400,000 TL as the setup cost for one ATM is 100,000 TL. The budget for opex is fixed at 440,000 TL. Distance threshold is set to 0.6 km.
- Scenario IV: The budget for capex is increased by 100,000 TL and the budget for opex is increased by 60,000 TL compared to Scenario III and both are set to 500,000 TL.
- Scenario V: In this scenario, bank focused on customers and the distance threshold is increased to 0.7 km. The budget for capex and

the budget for opex are determined 400,000 TL and 440,000 TL as in the Scenario III.

- Scenario VI: The budget for capex is increased by 100,000 TL and the budget for opex is increased by 60,000 TL compared to Scenario V and both are set to 500,000 TL. On the other hand, distance threshold is fixed at 0.7 km as in Scenario V.

The single-objective optimization models and GP model for each scenario given above were solved using Gams software on Intel i7 3.6 GHz personal computer with 8.0 GB of memory. In each scenario, GP model yielded solution in less than 0.12 seconds. Solutions were produced according to the case where all of the goals are equally important. However, the solution of the model may change in accordance with the changes in the relative importance of the goals. The solutions of the model are presented for the scenarios in Table 6. The locations of ATMs are denoted by "L".

Table 6. The Solutions of the Model

	Scenario I	Scenario II	Scenario III
Budget for Capex (TL)	350,000	350,000	400,000
Budget for Opex (TL)	380,000	440,000	440,000
Distance threshold (km)	0.6	0.6	0.6
G_1	14.75	15.57	15.57
G_2	4.00	4.00	4.00
G_3	892.14	480.01	480.01
	Scenario IV	**Scenario V**	**Scenario VI**
Budget for Capex (TL)	500,000	400,000	500,000
Budget for Opex (TL)	500,000	440,000	500,000
Distance threshold (km)	0.6	0.7	0.7
G_1	19.01	19.45	22.89
G_2	4.00	4.00	4.00
G_3	238.02	469.09	227.11

The first six locations (L1, L2, L3, L4, L5, L6) are belong to the bank we worked with, whilst the rest of 59 ATMs belong to the 14 different competitors.

According to the Scenario I, three of the locations of bank's existing ATMs (L1,L2 and L5) are altered with the competitors' locations (L7 and L33). Thus, total number of ATMs decreased by one. Scenario II resulted exactly similar with the Scenario III, and suggests removing the ATM in L2 and L5 for deploying two new ATMs at the competitors' locations (L33 and L37). However, in Scenario IV, bank needs to deploy 7 ATMs in total. Two new ATMs are located in L7 and L33 whilst ATM in L2 needs to be removed. In conclusion, first four scenarios commonly conclude to deploy ATMs in L33; moreover, L33 is located in the district where bank does not have any ATMs. Scenario V suggests removing two of bank's ATMs, which are located in L2 and L5 and deploying two new ATMs in L7 and L19. On the other hand, in Scenario VI, bank needs to remove only L2, and deploy the same ATMs in Scenario V. ATM located in L2 is eliminated for each scenario and five candidate locations (L7, L17, L19, L33, L37) are determined to focus on.

These scenario analyses provide an opportunity to simulate different cases and observe the results before implementing them. As a result of the proposed approach, bank becomes able to evaluate alternative locations and decide the most acceptable solution by examining the required resources and the distance that customers are allowed to travel.

Target and actual values for the first goal that aims to maximize the weighted total score based on each scenario are depicted in Fig.4. It is seen that unwanted deviation from the target level in Scenario II is about 0.01%, whilst 15% in Scenario VI.

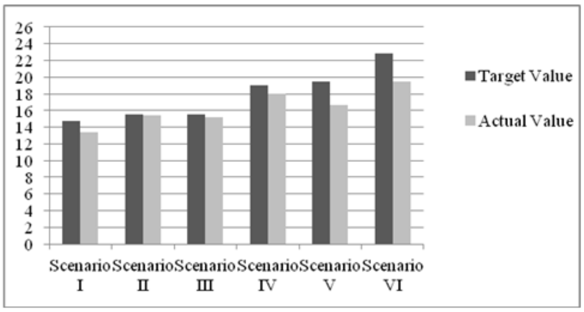


Fig.4. Results for Weighted Total Score

Target and actual values for the second goal that aims to minimize total number of ATMs based on each scenario are presented in Fig.5. In none of the scenarios, the target level is exactly achieved while the largest deviation 75% in Scenario IV and Scenario VI.

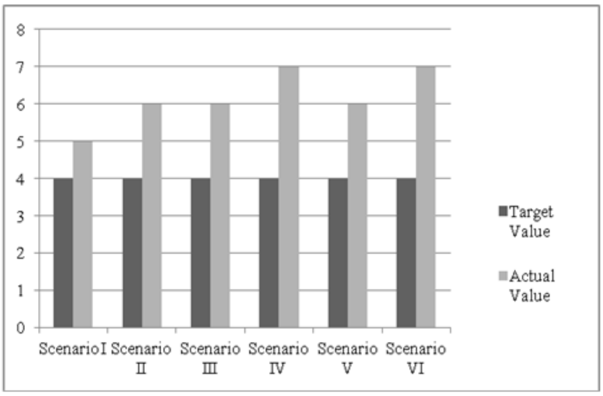


Fig.5. Results for Total Number of ATMs

Target and actual values for the third goal that aims to minimize total weighted distance traveled based on each scenario are showed in Fig.6. In Scenario IV, the target value is exactly achieved, while in the other scenarios, the deviation is around %1, %2, %2, %3 and %7, respectively. Scenario VI yielded to the maximum deviation of for the minimization of the total weighted distance objective.

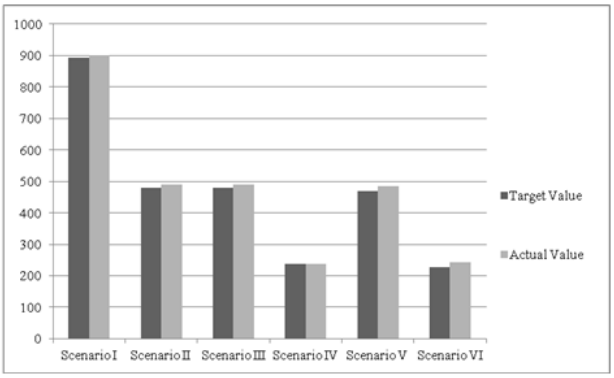


Fig.6. Results for Total Weighted Distance

Based on the scenario analysis, decision group decided to implement ScenarioV since this scenario enables to increase the total weighted score and decrease the total weighted travel distance. Although Scenario VI has higher score and smaller travel distance, the bank did not intend to deploy more ATMs due to set up and operational costs. Scenario V concludes to maintain the existing ATMs located in L1, L3, L4, and L6 and remove the existing ATMs located in L2, and L5. Instead of the removed ATMs, it suggests to deploy two ATMs to L17 and L19.

3.5. Phase 5: Visualizing the locations

We utilized Google Earth Pro software to visualize the solutions of the problem. In the model, since the application region is Besiktas and subregions are its districts; it is helpful for DM to see the borders of each district and locations of ATMs. The location of Besiktas in Istanbul map is shown in Fig.7.

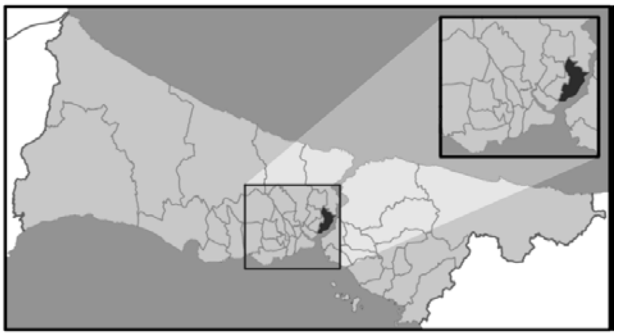


Fig.7. The location of Besiktas on Istanbul city map

Wikimapia.org is a free mapping tool that enables users explicitly mark polygons on a map to indicate places of interest. Therefore, “Ge.kml”, a free add-on was used to obtain the borders of each district and display these borders on Google Earth. The borders of districts were validated by the data which is provided by Istanbul metropolitan municipality website and the districts of Besiktas are presented in Fig.8.

Fig.8. The districts of Besiktas on the map

Moreover, the coordinates of ATM locations, which were in Ms Office excel format, were converted into the kml (Keyhole Markup Language) format, as the Google Earth only accepts the data in this format. The locations of 65 ATMs are depicted in Fig.9.

Fig.9. The locations of ATMs.

The results of the Scenario V are visualized and presented in Fig10. as the bank decided to follow this scenario. ATMs in L1, L3, L4, and L6 were decided to maintain, whilst ATMs in L2 and L5 were concluded to be removed. Moreover, L17 and L19 represent the locations that the model suggests to deploy new ATMs.

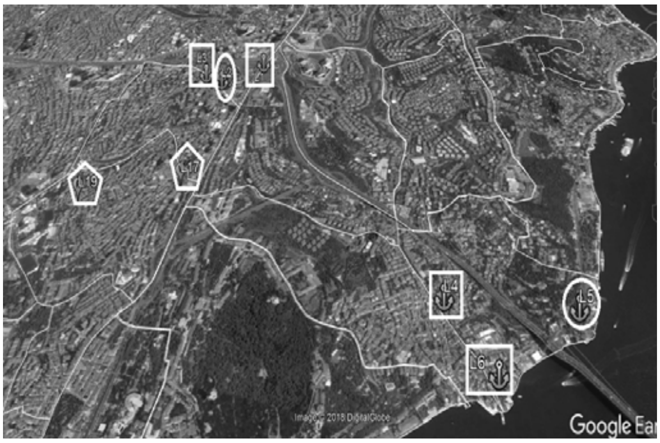


Fig.10. The results of Scenario V

4 Conclusion

In this paper, we proposed a new hybrid systematic approach to solve ATM location problem that applies to ANP and weighted goal programming model. ANP was utilized for determining the relative weights of location factors, which were used for calculating score of sub regions.

Three objectives were defined to maximize the weighted total score of locations, minimize the total number of ATMs, and to minimize the total weighted distance that customers travel to reach the ATMs. We presented a real world case study for a Turkish bank, which is among the top ten private banks in Turkey, to demonstrate the applicability and validity of the model.

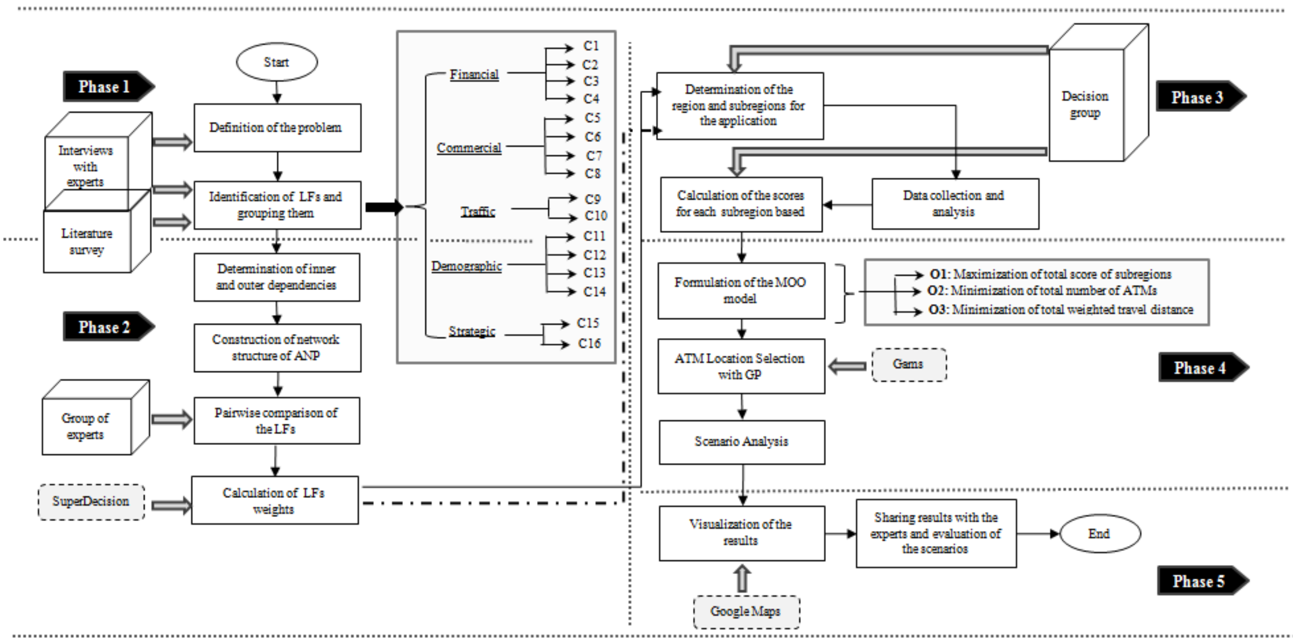
The locations and number of ATMs were determined as a result of the model. The most beneficial aspects of the presented approach can be stated as follows:

a. The model considers both the multi-objectivity nature of the problem, and includes subjectivity of the decision maker by assessing the attractiveness of locations.
b. The model enables the DM to make tradeoffs between conflicting objectives and evaluating different solutions.
c. The model is capable of performing what-if scenarios related to ATM location strategy. Accordingly, the model can be simply adjusted to varying resource commitments and service policies.
d. The proposed approach can be easily employed and give satisfactory solutions not only for ATM location problem, but it may be also applied for other service facility location problems.

We hope this research aids to decision makers who are struggling to make decisions on ATM location selection. Future work will focus on solving the problem with evolutionary multi-objective optimization methods and comparing the yielded results with the holistic approach.

Appendix:

Proposed Approach for ATM Deployment Problem



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