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LOCATING SEARCH AND RESCUE STATIONS IN THE AEGEAN AND WESTERN MEDITERRANEAN REGIONS OF TURKEY

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ABSTRACT

The service of present Search and Rescue (SAR) stations in the Aegean and the Western Mediterranean regions of Turkey are not sufficient to meet the demands of the Turkish Air Force. This article gives an outline about the study of seeking optimum locations of new SAR stations. The number of SAR stations required to cover all areas of operation becomes a very decisive element in finding the optimal coverage of the operation area by these stations. The problem of finding the optimum SAR locations can be modeled as a maximal covering location problem (MCLP). Additional constraints are added to set standards on various issues in the regions. Main emphasis is given to finding the minimum number of SAR locations that achieves maximum coverage in the operation area. The model is coded and solved with an optimization software (LINGO 5). The solution shows the location of SAR stations and the total coverage in the area based on the operational capacity of SAR units. Several scenarios are examined and the results are then analyzed and presented.

***Key Words**: Location Problem, SAR, Facility Problem, MCLP,SCP.*

1. INTRODUCTION: SAR ACTIVITIES

Turkey's National Search and Rescue (SAR) Plan is derived from international and domestic military agreements between authorities sharing a common interest. In practice, Search and Rescue is conducted with a spirit of cooperation between relevant authorities, and procedures exist to transfer a Search and Rescue incident between base authorities. The ideal arrangement is the seamless provision of Search and Rescue resources to an aircrew or unit in distress. The nature of Turkey's National Search and Rescue Plan demands a fairly flexible approach to Search and Rescue operations. Many Search and Rescue response units are dedicated to the task and are kept on stand-by at air bases.[11]

The purpose of SAR activities in the Turkish Air Force is to search for air crew and passengers in case of an accident, and execute any rescue mission as soon as possible. In wartime, however, this purpose includes bringing back the national and allied crew members from behind enemy lines to friendly territories where medical first aid can be supplied.[10]

2. LOCATION PROBLEMS

2.1 Basics of Location Problems

Location problems seek the best locations for service facilities such as fire stations, military installations, airports, or warehouses. The mathematical structure of a location problem depends on the region available for the location and on how we judge the quality of a location. Consequently, there are many different kinds of location problems, and the literature offers a variety of solution techniques.[8]

Location theory was first formally introduced in 1909 for locating a single warehouse to minimize the total travel distance between the warehouse and a set of spatially distributed customers. A number of authors in the 1950s and 1960s considered the problem of facility layout and design. Before the mid-1960s, however, work in the field of location theory consisted primarily of a number of separate applications not tied together by a unified theory. Interest in location problems was sparked by Hakimi who considered the general problem of locating one or more facilities on a network to minimize the travel distances in the network. Since then, considerable research has been carried out in the field of location theory.[1]

Basing or coverage type problems often are treated as location problems. The goal in location problems is to locate service facilities to minimize some cost function or to maximize the amount of demand for service that can be satisfied. In addition, fundamental to modeling of location decisions is some measure of proximity. While specific point-to-point distances are often used, the concept of coverage is a well-known alternative. The norm of partitioning inter-point distances based on some distance standard has been employed extensively in location literature for over thirty years. Location models fit into two broad categories based on whether coverage is required or optimized.[5]

2.2. Definition and Solution Techniques

According to one general definition, a location problem is a spatial resource allocation problem. In the general location paradigm, one or more service facilities (servers) serve a spatially distributed set of demands (customers).[1] Another source states that the plant location problem represents an idealization of a variety of practical decision problems.[7]

When we look at the solution procedures, we see both optimization and heuristic techniques. Optimization techniques include mixed integer programming, which is the most straightforward of the methods for optimizing location problems. The objective here is to optimize a linear cost function subject to constraints describing available service. Another optimization technique used is Lagrangian optimization. These method results in a much smaller mathematical formulation than integer programming, but it may become more difficult to solve. Heuristic techniques, on the other hand, have been developed to provide feasible solutions quickly that are acceptably close to the optimum. Heuristic techniques are used when exact methods for finding optimum solutions to location problems become too time consuming.[6] The primary algorithm used today to solve integer programs is the simplex algorithm with branch-and-bound applied to the relaxed integer program. There are many commercially available linear solvers, such as LINDO and CPLEX. There are also many heuristic solution approaches to integer programming problems and large zero/one problems [5]. Table 1 shows solution and evaluation techniques for location models.

2.3. Location Problem Types

Two versions of the location covering problem are the set covering problem (SCP) and the maximal covering location problem (MCLP). The SCP involves finding the minimum number of facilities required to cover a given set of demand points. The covering constraints are usually based on some easily determined metric such as distance or time-of-travel. On the other hand, the limited nature of most budgets can make covering all customers impractical. The MCLP attempts to address this problem by locating a limited number of facilities to cover the maximum number of, but not necessarily all, demand points. If all demand points are covered by the given number of facilities, the problem is equivalent to the SCP.[4] Table 2 presents the relationship between the SCP and MCLP. The SCP and the MCLP are extremely powerful tools in location analysis. Applications of these covering models include the location of daycare facilities, fire stations, bus stops, emergency services, computer service centers, airports, and military bases. Extensions to the original models may include multi-objective formulations, hierarchical location schemes, multiple or backup coverage, and facility capacity.[9]

Another version of location covering problems is the maximal expected covering location problem (MECLP). The MECLP has been used extensively in analyzing locations for public service facilities. The MECLP accounts for the possibility a covered demand point is not serviced since all facilities capable of covering the demand are engaged serving other demands. The formulation is an integer program. In industrial contexts, facilities may be unable to respond to demands due to inclement weather, labor conditions or facility maintenance needs.[2] To preclude this situation, we would therefore like to have more than one facility capable of covering each demand point or node, particularly those nodes that generate large numbers of demands. This idea is also applicable to the location of SAR stations. Here, the primary objective is to cover all the demands with the minimum number of facilities. Another objective of the SAR location problem is to maximize a measure of multiple coverage.[3]

3. ORGANICS OF THE PROBLEM

3.1 Problem Definition

The following scenario describes the problem.

The Turkish Air Force wants to locate some new SAR stations to increase its capabilities in the Aegean and Western Mediterranean regions. The current capability is not adequate to meet air force demands. The major considerations are number of stations and the coverage area of those stations. The Air Force wants to obtain maximum coverage with a limited number of stations in the region.

There are some possible candidate points where the SAR stations can be located and certain demand points that must be served. Every candidate point has meteorological and geographical and logistics values. The Air Force has established standards for these values. Resources limit the number of additional stations. All stations use similar SAR helicopters. Each candidate point's coverage area is known. Every demand point has an importance value. Each demand point's importance value, known as the bonus value is based on the frequency of missions flown around that point. The region is a holiday resort for tourists from inside and outside Turkey, so the Air Force does not want to interfere with tourist issues in the region.

Given this scenario, the problem is to locate a limited number of SAR stations to obtain maximum coverage.

Table 1. Some Solution Techniques for Location Models

Exact Solution Techniques	Heuristic Solution Techniques	Techniques for Evaluation of Heuristics
Analytical Solution/Optimality Result Integer Programming/Branch and Bound Dynamic Programming/Backtrack Programming Convex Programming Other	Exchange Heuristics Greedy ("Add") Heuristics Drop Heuristics Sequential Location and Allocation Solution of an Approximate Problem Solution of a Relaxed Problem Solution of a Restricted Problem Tabu Search Genetic Algorithms Other	Bound on Optimal Solutions Worst Case Analysis Probabilistic Analysis Statistical Evaluation Stopping Rule

Table 2. Relationships Between SCP and MCLP

Problem	Number of Facilities	% Demand Coverage	Coverage Distance
SCP	Objective function (min.)	100%	Exogenous
MCLP	Exogenous	Objective function (max.)	Exogenous

3.2. Scope and Objectives

Placing SAR stations may be regarded as a facility location problem. In a review of analytic models for locating facilities, Erkut and Neuman [5] state:

… we judge the site election stage to be too complex for accurate representation using an analytically tractable single-objective model…. Current models can be used to generate a small number of candidate sites, but the final selection of a site is a complex problem and should be approached using multi-objective decision making tools…. Further, reporting of such applications would benefit practitioners and researchers…

In this study there are two objectives. One is represented in the objective function, and the other one is modeled as a constraint. This partitioning of objectives makes the problem easier to solve. The basic objectives for this study are to:

Maximize coverage in the region.

Limit the number of stations.

In this study, the problem is dealt with by applying location problem techniques. An integer programming model is developed and solved. This study only reveals the location of SAR stations and it does not deal with the basing issues of the stations. Basically, the scope of this research is limited to the location stage of the problem. The research presents analysis of the results, makes recommendations and indicates potential extensions of the research.

3.3. Assumptions

The problem of locating SAR stations is a location problem and we do not plan to deal with basing issues. So, we make the following assumptions;

This research does not reflect the official policy of the Turkish Air Force.

Since the cost of locating each candidate point is assumed the same, therefore cost is not included in this problem.

Similar helicopters are used at the SAR stations. Although their attributes are realistic, they are called Helicopter X

Fixed distances from the candidate points are defined to indicate demand points.

Demand points and candidate points are generic. In other words, they are notional points in the region.

Basing issues are not included. The study examines only SAR location selection. It does not deal with personnel, equipment, design, or training issues at the stations.

There are a finite number of potential SAR station locations.

A demand point is covered if it is within the effective range of a SAR station.

Demand point coverage must be maximized.

The capacity and the performance of each SAR station are the same; however, their demand point coverage is different.

3.4. Formulation Background

The optimum location of SAR stations in the Aegean and Western Mediterranean regions of Turkey can be modeled as an MCLP with a number of additional constraints. In the problem, there are candidate points that model the location of SAR stations. The solution shows the number of demand points that can be covered and which candidate points should be selected. Each candidate point has a coverage area.

Demand coverage is handled in two ways. At first, demand points are covered once, and then, with a minor modification, the coverage is increased to more than one Each demand point does not have to be covered; however, any uncovered demand point does not contribute to the value of the objective function. Furthermore, there are constraints on the maximum number of SAR locations, weather, geography and logistics.

There are two types of decision variables; one for demand points and one for candidate points. First, both types are introduced as binary integer variables. This covers the demand points only once. Then the variables for the demand points are treated as general integer variables while the decision variables for the candidate points remain binary. This approach allows us to vary the constraint parameters and analyze results regarding these variations. In order to form some regional constraints, each candidate point is given a logistics, weather and geography value. These values are based on the candidate point's conditions with respect to these areas. For the solution, selected candidate points have to be above the average value for these areas. In other words, the sum of candidate point values for each additional constraint has to be above some level for the candidate point to be feasible. This level is a reasonable numerical value based on the conditions of that area.

3.5. Candidate Point Inclusion

Candidate point inclusion strategy is based on regional issues, and the various advantages and disadvantages of the selected points. There is no strict guideline that depicts this inclusion process. One major issue is the proximity of candidate points. There are many sites that can be included as candidate points, and each one has different characteristics. Therefore, we try to include those points close to each other in order to evaluate their coverage capabilities and regional issues such as geographical, logistical and meteorological advantages. In our model we have 152 candidate points.

3.6. Demand Point Selection

Demand point selection is vital to this model, since demand points define the coverage of operation areas. Selecting the demand points defines possible rescue points. Since, an accident may happen anywhere; demand points must represent all areas.

These points represent the entire area of operation. In our model there are 100 demand points. The model tries to maximize the coverage of these demand points. The relationship between the candidate point and the demand point variables is shown in Figure 1.

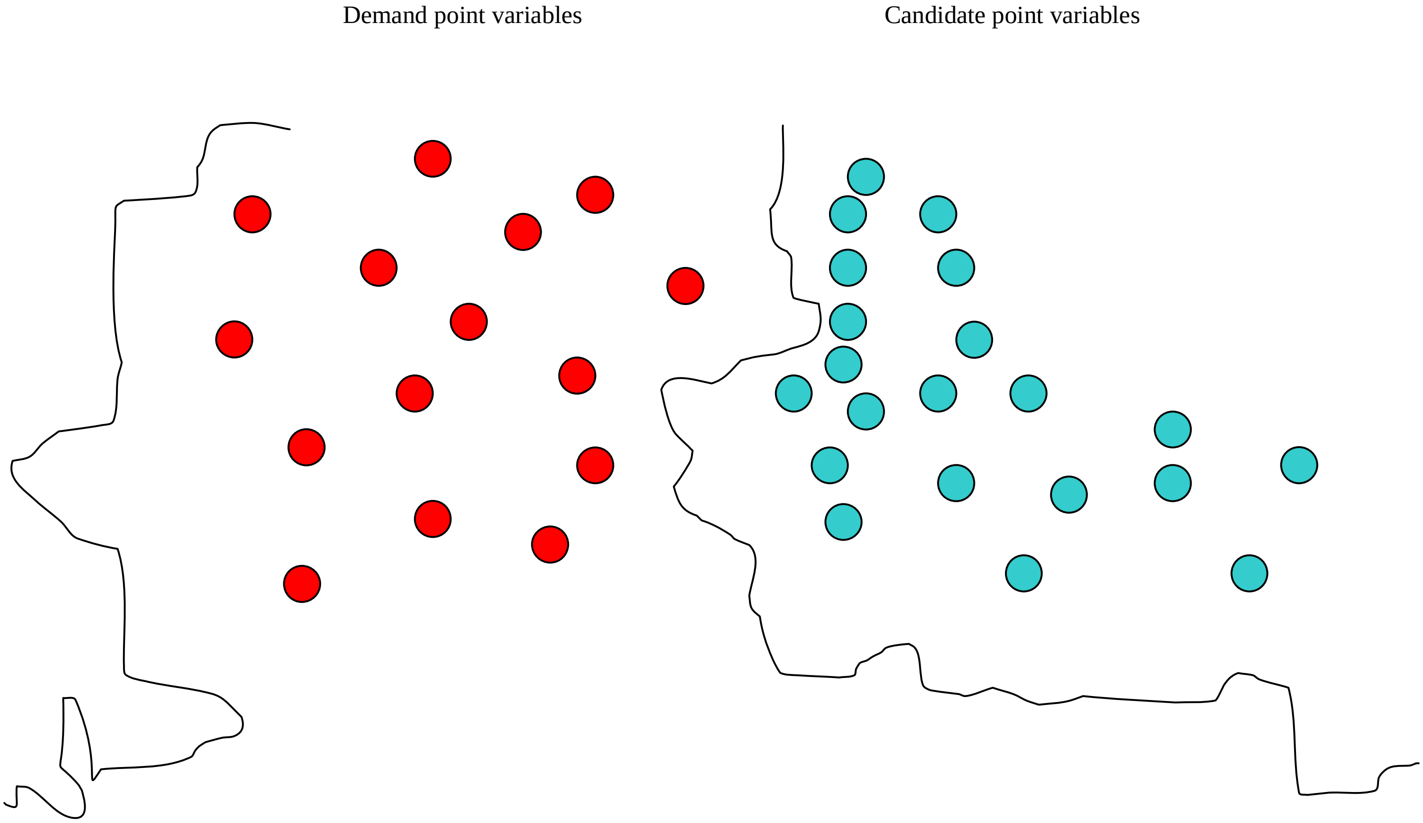

Figure 1. Candidate points and Demand points

3.7. The Mathematical Model

The mathematical model can be described as an MCLP with additional constraints and variables.[9] A typical MCLP is formulated mathematically as :

Maximize $Z = \sum a_i \bullet y_i \quad i \in I$

Subject To:

$\sum x_j \geq y_i \quad \forall i \in I, \quad j \in Ni$

$\sum x_j \leq P \quad j \in J$

$x_j \in \{0,1\} \quad \forall j \in J$

$y_i \in \{0,1\} \quad \forall i \in I$

where I = set of demand points, J = set of candidate facility location sites.

x_j (candidate points) = 1 if site at location j is occupied, 0 otherwise.

y_i (demand points) = 1 If demand point at i is covered, 0 otherwise.

a_i = the value of covering demand point i for i = 1,…..m

P = the number of facility location sites that can be occupied.

3.8. Model Formulation

Our formulation of the SAR location problem is:

Maximize $Z = \sum a_i \bullet y_i \quad i \in I \quad (1)$

S.T.

$\sum x_j \geq y_i \quad \forall i \in I, \quad j \in Ni \quad (2)$

$\sum x_j \leq P \quad j \in J \quad (3)$

$\sum L_j \bullet x_j \geq N_L \bullet \Sigma x_j \quad j \in J \quad (4)$

$\sum G_j \bullet x_j \geq N_G \bullet \Sigma x_j \quad j \in J \quad (5)$

$\sum W_j \bullet x_j \geq N_W \bullet \Sigma x_j \quad j \in J \quad (6)$

$J = \{1 \ldots 152\}, \quad I = \{1 \ldots 100\}$

$x_j \in \{0,1\} \quad \forall j \in J,$

$y_i \in \{0,1\} \quad \forall i \in I,$

where :

I = set of demand points

J = set of candidate SAR location sites

x_j = 1 if SAR site at location j is occupied, 0 otherwise.

y_i = 1 if demand point i is covered, 0 otherwise.

a_i = the value of covering demand point i for i = 1,…..m

P = the number of SAR sites that can be occupied.

S = maximum covering distance

d_{ij} = distance from each demand point i to each SAR site j.

$N_i = \{ j \in J \mid d_{ij} \leq S \} \quad \forall i \in I$

N_L = the minimum value that has to be met by limiting constraint (4), to set the standard for logistics.

N_G = the minimum value that has to be met by limiting constraint (5), to set the standard for geography.

N_W = the minimum value that has to be met by limiting constraint (6), to set the standard for weather.

L_j = the individual logistics value that SAR site j takes.

G_j = the individual geography value that SAR site j takes.

W_j = the individual weather value that SAR site j takes.

Decision variable demand points (y_i) can be changed to general integer to allow multiple coverage of the demand. This increases the objective function value and effectiveness of the SAR stations. The effects of this change are compared and analyzed.

Constraint (2) is the coverage constraint. The candidate SAR location sites cover the fixed demand points. Each candidate point has a certain number of demand points it can cover; likewise, each demand point has a set of candidate points which cover it.

Constraint (3) shows the limit on the number of SAR sites. In other words, it indicates how many points may be assigned as SAR sites.

Constraints (4), (5), and (6) are the limiting constraints for logistics, geography and weather. As we have mentioned before, each candidate point has its own characteristics for these issues. Therefore, last three constraints set a standard on each one of these characteristics.

3.9. Model Restrictions and the Solution

There are some restrictions in the model that we need to explain. These restrictions affect the model and its solution. The restrictions are on the number of SAR stations, coverage, and regional considerations. The main emphasis should be given to the coverage restriction because it may change the optimal solution.

Demand point coverage is not fixed. It may change due to operational conditions. Helicopter X may have a range limit, but this is not a fixed value. Therefore, restrictions on variations in helicopter range require us to take a parametric approach. By changing parameter values we can investigate the differences caused by variations in the helicopter range.

The constraints also change with the coverage distances. Thus, we examine the problem in three stages. First, we solve the problem with the normal coverage distance, then we reduce the coverage distance to abnormal coverage distance, and finally we apply the worst-case scenario. Since the coverage of demand points change in each case, coverage rates differ, and we analyze the differences.

4. PROBLEM SOLUTION

4.1. Results and Analysis

Results are examined under three basic scenarios. These scenarios differ by coverage distances. In each solution, the maximum coverage with the minimum number of SAR stations is found. After finding these solutions, a combined solution is produced. The combined solution is devised to achieve the separate solutions' maximum coverage rates under one solution. Furthermore, for each scenario, demand point variables are first treated as binary variables and then as general integer. Binary solution applies to the solutions where the demand points are covered at least once. The general integer solution gives credit to demand points covered more than once. This model was created to help the decision-maker. Since the 150-mile scenario has the most extensive formulation, one such approach suggests an application of the 150-mile solution to the other scenarios. We also examine an application of the combined 150-mile and 120-mile solutions to the 80-mile scenario. Consecutively, we produce three options for the decision-maker to examine. A sensitivity analysis can be applied to the model in order to show the impact of changing certain constraints of the model.

4.2. Solutions for Each Scenario (Separate Solutions)

There are three basic scenarios based on helicopter coverage distances: 80-mile, 120-mile, and 150-mile scenarios. We find solutions for each scenario with all demand point variables binary and general integer. We first examine each scenario separately and then compare their results. The main emphasis is given to the solutions with binary variables for each case, because it is easy to evaluate the rate of coverage when using binary variables, and coverage is important to pilots.

4.2.1. 80-Mile Solution

The goal is to find the maximum coverage with the minimum number of SAR stations for an 80-mile scenario. Table 3 shows the parametric analysis for this scenario.

The best coverage rate is 52% (52 of 100 demand points) and can be achieved using 9 SAR stations. Naturally, as we increase the number of SAR stations in the model, the redundant coverage increases as seen in the GIN SOL column.

If the redundant coverage is important, 9 SAR stations may not be adequate as only 28% of the demand points get covered even tough demand points are covered totally 110 times. Clearly, the form of the objective function drives which SAR stations are picked and thus which demand points have any coverage.

Table 3. Solution Report for 80-Mile Scenario

# of SAR Stations	BIN SOL	GIN SOL
30	52	291
25	52	255
20	52	215
15	52	171
10	52	121
9	52	110
8	51	99
7	50	95
5	47	65
3	34	41
1	13	13

In Figure 2, binary solution shows a stable solution structure of 52, while the general integer solution's objective value constantly decreases as the number of SAR stations decreases. Binary solution's coverage is the same until the number of SAR stations is reduced to nine. After nine stations, coverage decreases. A single SAR station has a coverage rate of 13%.

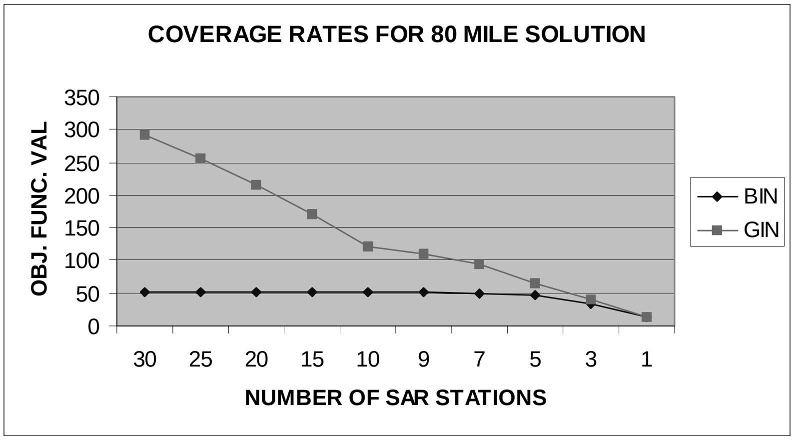

Figure 2. Objective Function Values vs. Number of SAR Stations

4.2.2. 120-Mile Solution

This scenario increases SAR station range from 80 miles to 120 miles. Table 4 summarizes the solutions with different numbers of SAR stations. Increased range means increased coverage with fewer SAR stations; 77% coverage using 8 SAR stations.

The general integer formulation encourages extra coverage. When we encourage multiple coverage of the demand points, we still cover 56% of the demand points with 8 SAR stations. Figure 3 plots the data from Table 4. More SAR stations can increase redundant coverage but not the percentage of coverage. A single SAR station covers 23% of the demand points.

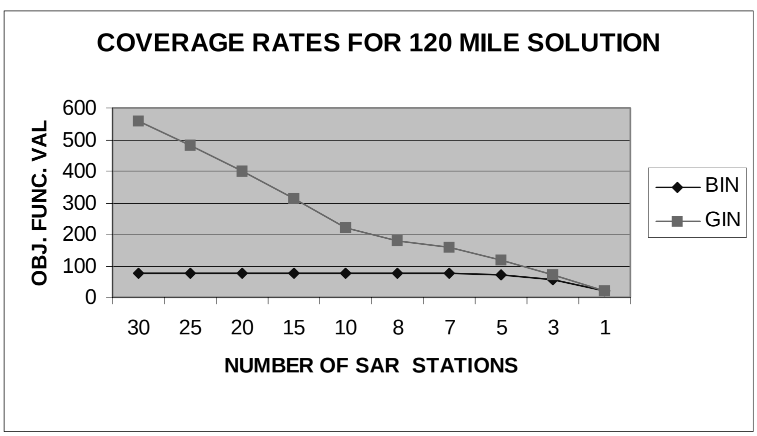

Figure 3. Objective Function Values vs. Number of SAR Stations

4.2.3. 150-Mile Solution

In this scenario, SAR units have a coverage distance of 150 NM. Table 5 shows the results with different numbers of SAR stations.

In this scenario, 100% coverage is obtained using 6 SAR stations and this is the accepted solution. Solving with 8 SAR stations, and rewarding multiple coverage, the demand points are covered 243 times. However, the operation area's coverage rate drops to just 55%. This is not likely to be acceptable. Figure 4 plots the data from Table 5, yielding the same insights as gleaned from Figure 2 and Figure 3

Table 5. Solution Report for 150-Mile Scenario

Number of SAR Stations	BIN SOL.	GIN SOL
30	100	970
25	100	837
20	100	698
15	100	548
10	100	385
6	100	243
5	99	205
3	87	126
1	43	43

The main purpose of these results is to show the maximum coverage for each scenario. The objective function form drives the SAR station selection and coverage Table 6 summarizes the best results obtained. Favoring multiple coverage reduces percentage coverage. Next, we must find a solution to maximize coverage in all scenarios

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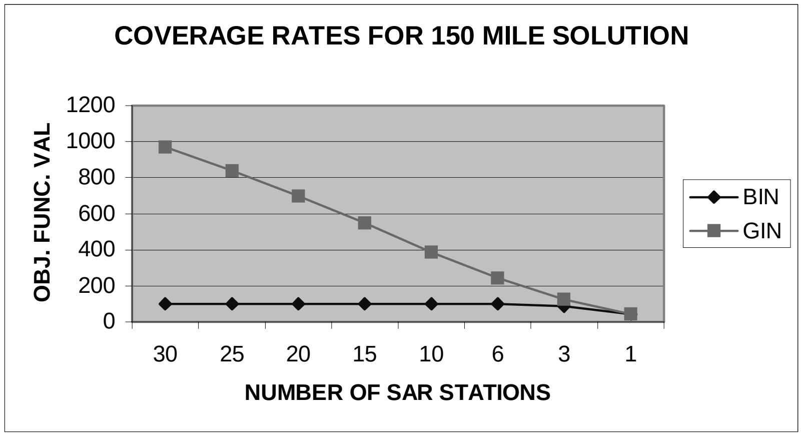

Figure 4. Coverage Rates For 150 Mile Slotion

Table 6. Summary of the Results

Scenarios	Number of Stations	Objective Function Value	Coverage Rate in the Operation Area (%)
80-mile(bin)	9	52	52
80-mile (gin)	9	110	13
120-mile (bin)	8	77	77
120-mile (gin)	8	179	56
150-mile (bin)	6	100	100
150-mile (gin)	6	243	55

4.3. Combined Solutions

The different scenarios produced different answers based on different candidate points. In order to locate SAR stations, we need some combined solution that maximizes coverage in all scenarios with some minimum number of SAR stations.

To find a single solution, we take the candidate points that satisfy the maximum coverage for each scenario, and the alternative optimal solutions. We take the union of these sets and find a solution set that maximizes coverage in all scenarios with the minimum number of SAR stations. Table 7 shows these sets and the combined solution set. These solutions show coverage first and then minimize the number of SAR stations.

The main structure of the model produces several alternative optimal solutions. In the combining process, the main emphasis is given to the coverage issue. Second consideration is to keep the number of SAR stations as low as possible. Therefore, the solution basis is different from those found in the scenarios. Nonetheless, in order to maximize the coverage for each scenario in the combined solution, the number of SAR stations has to be at least 11.

Table 7. Solution Sets

Solutions	Selected Candidate Points (X)	# of Stations	Coverage Rate (%)
80-Mile	6, 33, 34, 56, 72, 98, 118, 123, 142	9	52
120-Mile	8, 31, 33, 62, 64, 72, 118, 142	8	77
150-Mile	6, 34, 70, 72, 105, 141	6	100
Combined	1, 6, 33, 34, 56, 63, 72, 73, 118, 123, 142	11	100, 77, 52

Table 7 shows the combined solution set with the coverage rates. Table 8 summarizes the results of the combined solution for binary and general integer models with and without bonus values.

Table 8. Summary of the Combined Solution Results

Scenarios	# of Stations	Objective Function Value	Coverage Rate in the Operation Area (%)
80-mile (bin)	11	52	52
80-mile (gin)	11	105	52
120-mile (bin)	11	77	77
120-mile (gin)	11	192	77
150-mile (bin)	11	100	100
150-mile (gin)	11	328	100

A very nice feature of the combined solution is that, there is no degradation in coverage rate when redundant coverage is encouraged. There are also some differences between the separate and combined solutions of the scenarios. For the combined solution, the number of SAR stations is the same for each model. Objective function values and coverage rates may differ for each solution type.

The separate solution for 80 NM has more total multiple coverage than that of combined solution. On the other hand the combined solution surpasses the separate solutions for 120 NM and 150 NM coverage distances. This reflects the change in the number of times each demand point is covered.

For 80 NM and 120 NM solutions, objective function values are very close for combined and separate solutions when the bonus points are included. As for the 150 NM solution, the combined solution clearly overshadows the separate solution.

When we combine the solutions, we need more SAR stations to maintain the maximum coverage for each scenario. However, for almost all cases the combined solution results are better than the separate solution results.

Finally, we would like to show the results on the map in Figure 5. The map shows the approximate location of the SAR sites based on the results. This representation presents a better understanding of the solution. In addition, they are only <u>for demonstration, not for implementation.</u>

In Figure 5, there are 11 SAR locations, shown in the squares, along the Aegean and Western Mediterranean coastline of Turkey.

Figure 5. Demonstration of the Combined Solution

4.4. Conclusion

Three options were examined. The combined solution offers the best coverage rate using 11 SAR stations. The second option satisfies the maximum coverage for the 150-mile scenario, but its coverage rate is very low for the other cases. Because it uses the lowest number of SAR stations. The third option uses only 8 SAR stations, it produces near maximum coverage rates for the 150 and 120-mile scenarios, and its 80-mile scenario coverage is close to the maximum rate.

Overall, the best solution appears to be the combined solution. If there are cost considerations involved, the 150+120-mile solution should be considered. Lastly, application of 150-mile solution may be used when the other solutions are not considered.

5. RECOMMENDATIONS AND CONCLUSION

The problem of locating SAR sites was examined using MCLP. MCLP was formulated with additional constraints to create the current model. The model was solved using LINGO 5. The problem was handled in three scenarios that use the same model with minor changes. Once the basic solutions were obtained for several scenarios, the parameters concerning these solutions were changed and new solutions were produced. While one major solution was achieved, the problem was also analyzed using the output based on these changed parameters.

There are alternate solutions for each scenario. So for this reason, one major solution that combines these scenarios is developed and presented as the solution to be presented to decision-maker. The relationship among these solutions is also examined. The model and LINGO 5 code are very useful and can be used for similar types of problems.

The model successfully found the optimum sites where the SAR facilities can be located in the Aegean and the Western Mediterranean regions of Turkey. The minimum number of SAR sites that satisfy the maximum coverage in the region is found. Solution times are low, and the model is very easy and flexible to use. New constraints may be added whenever needed or present constraints can be modified for different type of scenarios.

5.1. IMPLEMENTATION AREAS

I would like to emphasize that generally, this problem is a location problem. Although it solves the optimum location of SAR units, it can be easily applied to other areas. Radar coverage, warehouse location, facility location with a given coverage and other similar kinds of MCLP models can be solved with a similar approach.

MCLP models are very common for location problems and have wide implementation areas. For this reason, with simple modifications the model proposed in this research could be used for civilian and military cases.

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Vita

Capt. M. Melih Başdemir was born on 30 September 1972 in İstanbul, Türkiye. He graduated from Kuleli Military High School in İstanbul, in June 1990. In the same year he entered the Air Force Academy in İstanbul and graduated as a 2nd Lieutenant with a Bachelor of Science degree in Industrial Engineering on 31 August 1994. Then, he went to Çiğli Air Force Base for undergraduate pilot training (UPT). During his UPT he was selected for Euro NATO Joint Jet Pilot Training (ENJJPT). So, he was assigned to Sheppard Air Force Base, Texas in February 1995.

He came back to Turkey as a military fighter pilot in April 1996, and proceeded to Konya Air Force Base, Konya for Introduction to Fighter Fundamentals (IFF) training with NF-5. After IFF training, Lt. Başdemir was selected for F-16 training; he completed his F-16 training at Akıncı Air Force Base, Ankara in April 1998. His assignment was to Diyarbakır Air Force Base, Diyarbakır. While he was flying as a wingman in 181 Fighter Squadron, he was chosen for Air Force Institute of Technology (AFIT). In August 1998, he entered the Graduate School of Engineering, AFIT. He came back to Diyarbakir after graduating from AFIT in March 2000. He flies F-16 in Diyarbakir.

Capt. Başdemir is married and has two sons. He is also a member of Tau Beta Pi (TBP), the American National Engineering Honor Society.