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# MODELLING AND OPTIMIZATION OF THE EXAM INVIGILATOR ASSIGNMENT PROBLEM BASED ON PREFERENCES

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**ABSTRACT**

The assignment process of invigilators to the exams could be difficult and time-consuming process when there are too many exam centers and the invigilator who will assign. In particular, due to the constraints of assignment according to the characteristics of the invigilators, keeping the assignment process taking into account the officer's preferences and the fact that the test centers have a certain capacity makes the problem very complicated. In this study, the situation was considered as an assignment problem. To solve this complicated situation, we formulated the problem, with the constraints of the capacity of exam centers, type of the invigilator, type of centers and other restrictions. An algorithm for model implementation was developed and automation suitable to the algorithm was written in C# language. The model was then applied to the case of exam invigilators assignment at Open Distance Faculty of Anadolu University. All the assignment process time is reduced from weeks to several minutes.

***Keywords:*** *Examiner Assignment Problem, Optimization, Mathematical Modeling, Automated Assignment Systems*

## 1. INTRODUCTION

The assignment of personnel in appropriate positions in terms of their capabilities and characteristics increases staff satisfaction, optimizes resources utilization and increases performance. However, assigning personnel to appropriate positions in the context of a number of constraints is a complex problem. The assignment problems examine the distribution of a certain number of resources among the various targets. These problems have been subject to many scholarly works (Diaz 2001, Burkard 2002, Loiola, de Abreu *et al*. 2007, Oncan 2007, Pentico 2007, P. Tapkan 2008, K.Bhunia 2010, G. Liu 2011). The solution of problems in many different areas of life such as nurse assignment (Liang and Turkcan 2016, Wang, You *et al*. 2017), invigilator assignment (Hanum, Romliyah *et al*. 2015), airway fleet assignment (Subramanian, Scheff *et al*. 1994, Özener, Matoğlu *et al*. 2017), traffic assignment (Patriksson 2015, Poole and Kotsialos 2016), shift assignments(Hojati 2010) has been frequently researched in the literature.

The exam invigilator assignment problems, a type of assignment problem, are a problem that universities meet more than once each semester. There are several ways to solve this problem. One of these ways is the solving of the problem manually by a person who has a lot of knowledge and experience about the subject. In this case, the probability of making a mistake will be significant and the time to be spent according to the magnitude of the problem will also increase. Another solution method to the exam assignment problems is the using of mathematical models. In this case, the problem will be mathematical programming model, then the solution will be realized with the help of necessary algorithms. For example, Elizondo (Elizondo 1994) examined the problem of the assignment of n number of students to m number of schools in his study. The objective of their proposed model was to minimize the total distance. As a similar problem to invigilator assignment problem, Elloumi (Elloumi, Kamoun *et al*. 2014) studied the problem of the assignment of exams and classes. The objective of their model was to minimize the number of students that were not assigned. Karimzadeh and Zhai (Karimzadehgan and Zhai 2012) modeled a committee review team assignment problem as an integer programming problem and solved it by using an algorithm that was developed by them. In another study, a model was developed to assign an invigilator to exams for the Carleton University in Ottawa. The system combines special heuristics, genetic algorithm framework and ready software tools (Awad and Chinneck, 1998). Taha and Mansour (Mansour and Taha, 2015), used a solution for the proctor assignment problem based on the Bee Colony meta-heuristic algorithm. They stated that their proposed method maximized the preferences of proctors and balanced the workload of proctors.

In this study, we propose a new method and decision tool to assign invigilators to the exam centers. To accomplish this, an assignment system was designed that takes into account many constraints such as the invigilators' preferences, the detailed of previous exams and invigilators, the features of the centers.

The study started with the database creation process. This database contains information such as supervisors' titles, years of work, exams they have already assigned. While ensuring that the exams are carried out without errors, the comfort and satisfaction of the assigned invigilator are also taken into consideration. For this reason, to be re-created before each exam, a preference table consisting of centers where the invigilators would like to work is added to the database. In addition, since the characteristics of the examination centers are not the same in terms of transportation, comfort and social facilities, tables that are classified according to the characteristics of the centers are added to the database. In addition, the table has been added to the database to show which supervisors have been assigned to the centers in previous exams so that each supervisor can be equally assigned to different centers (Fig. 1). Then, a mathematical model was developed to provide the constraints of the problem. An algorithm that realizes this model has been developed and an automation written in C # language was presented to the university.

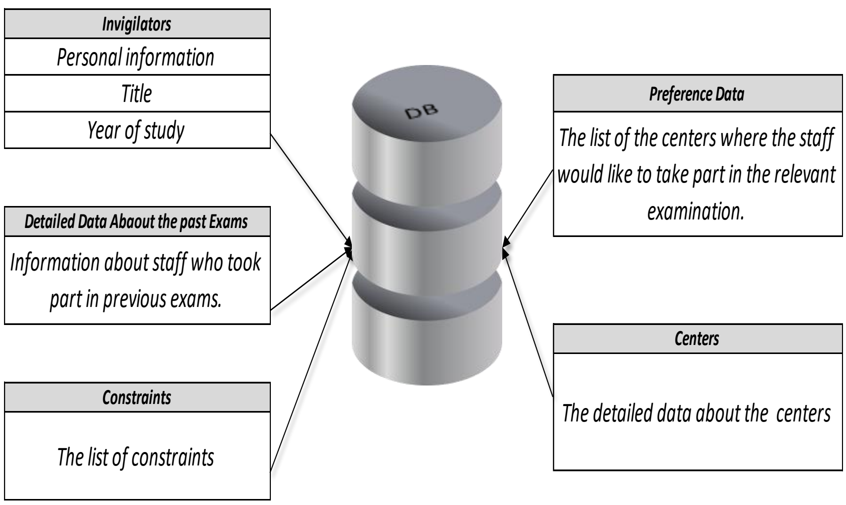


Fig. 1. The details of the created database

This study is an example of solving large-scale staff assignment problems that differ from standard supervisor assignment or exam scheduling problems. It provides very important tips on how to incorporate special cases that may be encountered in real life problems into models and how algorithms can be created in this direction. In the study, many special cases are mathematically modeled, such as the capacity constraints of the centers, detailed information about the invigilators to be assigned, the centers they prefer, the characteristics of the centers, the number of tasks the officials have previously received. Another difference from the other studies examined in the literature is the dimensional nature of the problem being studied in the study. The problem that is examined as an example is the process of assigning invigilator to examination centers to check exams that a university with an open teaching system has done throughout the country. Therefore, the characteristics of the test centers such as transportation, accommodation, number of schools to be audited are included in the appointment procedure.

## 2. MATERIAL AND METHODS

There are 1671 invigilators and 83 centers considered in this problem. The information on how many invigilators will be assigned to the center (the capacity of the center), the information about the invigilator (the title of the invigilator, the year of seniority, if the invigilator assigned to the center previously, etc.) are stored in the database. And the database in which the obtained data is stored, the created model and the assignment system are shown in Fig. 2.

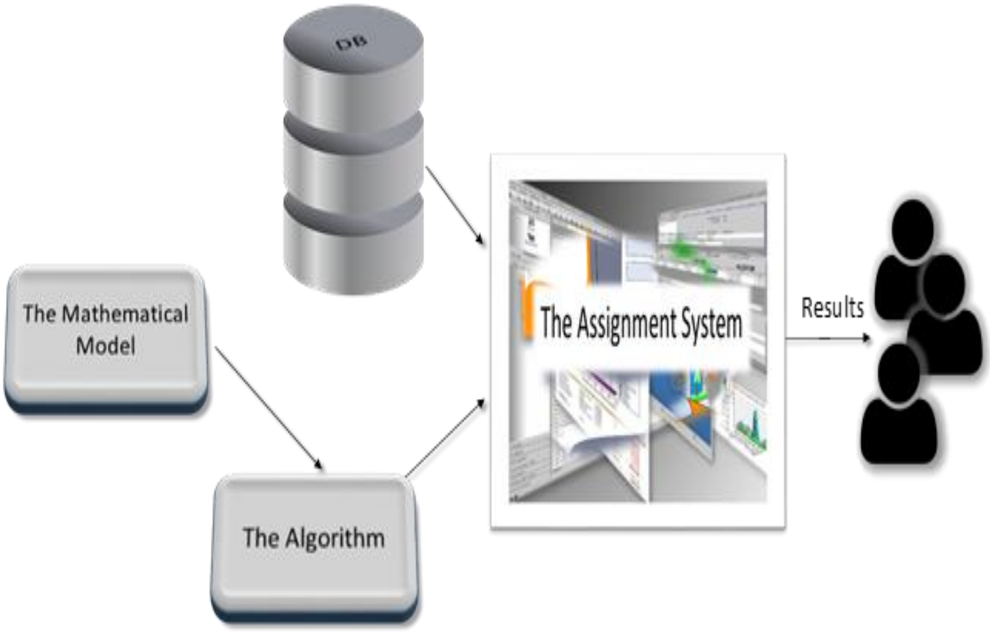


Fig. 2. The overview of the system

In this problem, all centers are divided into six groups according to their characteristics. The highest score was given to the group with the best features and the lowest score was given to the group with the worst features. In this sense, the other groups have scored from one to six. Then, in the past years, according to the information about which invigilators was assigned to which center, the score of the group where each center is located is determined as the score of invigilators. These points are used to give priority to the invigilators with low scores in order to perform a fair assignment. To reflect this in the mathematical model, the minimization of the total score of the invigilators is considered an objective function in the model. The assumptions of the problem are as follows:

- The invigilators should not be assigned to the center to which they were previously assigned;
- The invigilators that were assigned during the previous exam should not be assigned in the current exam.

### 2.1. The Proposed Mathematical Model

In this problem, the objective is to find the correct invigilator group in order to minimize the total score under the constraints. In the proposed model there are seven constraints, one decision variable(Ygm) and two indices that represent invigilators(g) and the centers(m).

Notation:
Model indices, parameters, and decision variables are given below:

Indices:
g=1…G, invigilator. There are G units of invigilators in the problem.
m=1…M, centers: There are M units of centers in the problem.

Parameters:

$P_g$ : The total score of the invigilator.

$Pr_g = \begin{cases} 1, & \text{If the title of the invigilator g is proffesor.} \\ 0, & \text{otherwise} \end{cases}$

$\mathbf{A_g} = \begin{cases} \mathbf{1}, & \textbf{If the title of the invigilator g is r. assistant.} \\ \mathbf{0}, & \textbf{otherwise} \end{cases}$

$S_m$= The number of the invigilator that must be assigned to the centre $m$.

$T_{gm}$ = The state of the invigilator $g$ to choose the centre $m$.

B(g,m) = The state of whether the grouping of centres agrees with the groupings of the centres that invigilators were assigned previously.

$\mathbf{D_g}$ = The semester of the exam that the semester of the last assignment of the invigilator g.

Decision Variable:

$\mathbf{Y_{gm}} = \begin{cases} \mathbf{1}, & \textbf{If the inv. g is assigned to the center m} \\ \mathbf{0}, & \textbf{otherwise} \end{cases}$

Model

$$Min\ Z=\sum_{m=1}^{M}\sum_{g=1}^{G}\left(P_g * Y_{gm} * T_{gm} * B(g,m)\right) \quad (1)$$

$$\sum_{m=1}^{M} Y_{gm} \leq 1 \qquad (g=1,...,G) \quad (2)$$

$$\sum_{g=1}^{G} Y_{gm} = S_m \qquad (m=1,...,M) \quad (3)$$

$$\sum_{g=1}^{G} Pr_g Y_{gm} \geq 1 \qquad (m=1,...,M) \quad (4)$$

$$\sum_{g=1}^{G} A_g Y_{gm} \geq 1 \qquad (m=1,...,M) \quad (5)$$

$$\sum_{g=1}^{G} D_g Y_{gm} = 0 \qquad (m=1,...,M) \quad (6)$$

$$Y_{gm} \in \{0,1\} \quad (7)$$

The total score of the invigilator $\boldsymbol{P_g}$ is calculated with the data stored in the database. This data includes the centers where the officers were previously assigned and the scores of these centers.

The objective function (1) minimizes the total score of the invigilator that is chosen and assigned to center m. The parameter Tgm is used for preventing the assignment of invigilator that did not choose the center with a big value, such as 1000. Constraint (2) ensures that each invigilator cannot be assigned more than one center. In constraint (3), the number of invigilators that is assigned to the center must be equal to the capacity of the center. Constraint (4) states that at least one invigilator who is professor must be assigned to each center, while constraint (5) ensures that at least one invigilator who is research assistant must be assigned to each center. The constraints (4) and (5) ensures that (upon management's request), at least one experienced, and one inexperienced invigilator should be assigned to each center. The constraint (6) ensures that the invigilator cannot be assigned in the same period as the previous assignment.

## 2.2 Proposed Algorithm

In order to apply the constraints, we developed an algorithm. The general approach of the algorithm is to give priority to the invigilator with the smallest score.

The constraint (6) ensures with the first step of the algorithm. In this step, the procedure is starts with the selecting the invigilator whose last assignment period is different from the present exams period. To agree with the constraints (4) and (5), which stated that at least one professor and one research assistant must be assigned to each center, the algorithm consisted of three main parts; i.e., find a professor, find a research assistant, and find other invigilators. The invigilator assigned to a center with the help of the algorithm are removed from the processing pool. Thus, this striker is not assigned to another center. In this way, an attendant whose mathematical model is developed can be assigned to a maximum number of centers. Thus, the constraint (2) in the developed mathematical model is ensured.

Each main part has own three iterations. In Fig. 3, there is the algorithm to find a professor to the centers.

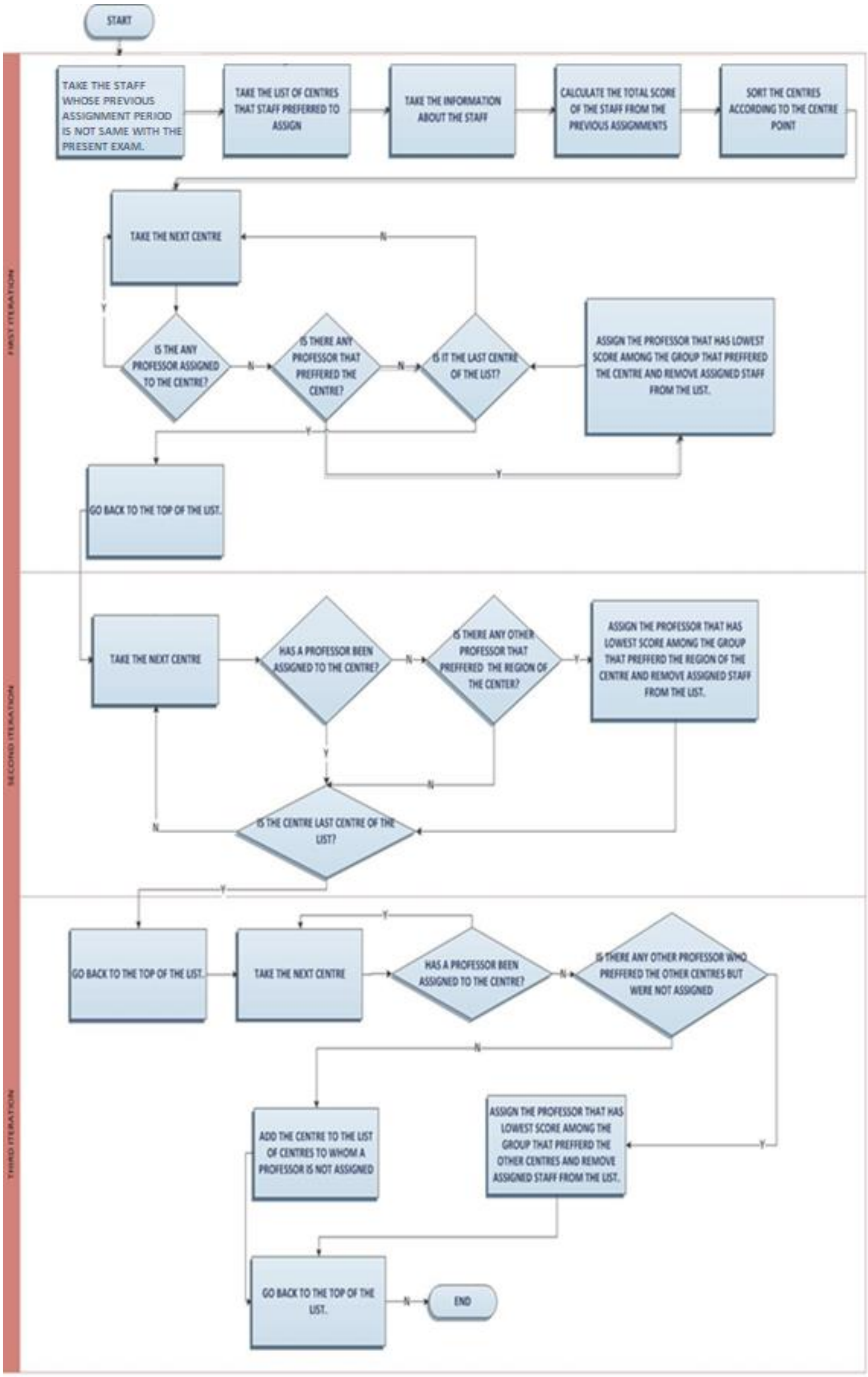


Fig 3. Find an Invigilator Who are a Professor

In the first iteration, a search was conducted for appropriate invigilators among the group that prefers that center, and this process was repeated for each center. In the second iteration, if an insufficient number of invigilators was assigned to the center, the appropriate invigilator was searched for among the invigilators that preferred another center in the same group as the original center but were not assigned it in the first iteration. This process was also repeated for each center. In the last iteration, if there was still an insufficient number of invigilator assigned to the center, the appropriate invigilator was searched for among the invigilators that were not assigned in the first two iterations.

After the assignment of invigilators who are a professor, the assignment of other invigilators who are the research assistant is performed. In Fig. 4, there is the algorithm to find invigilators, who are the research assistant, to the centers. It is ensured that the assigned officers are removed from the transaction pool by the help of algorithm. In this way, an attendant whose mathematical model is developed can be assigned to a maximum number of centers. After the assignment of invigilators who are research assistant, the assignment of other invigilators is performed. In Fig. 5, there is the algorithm to find an invigilator to the centers.

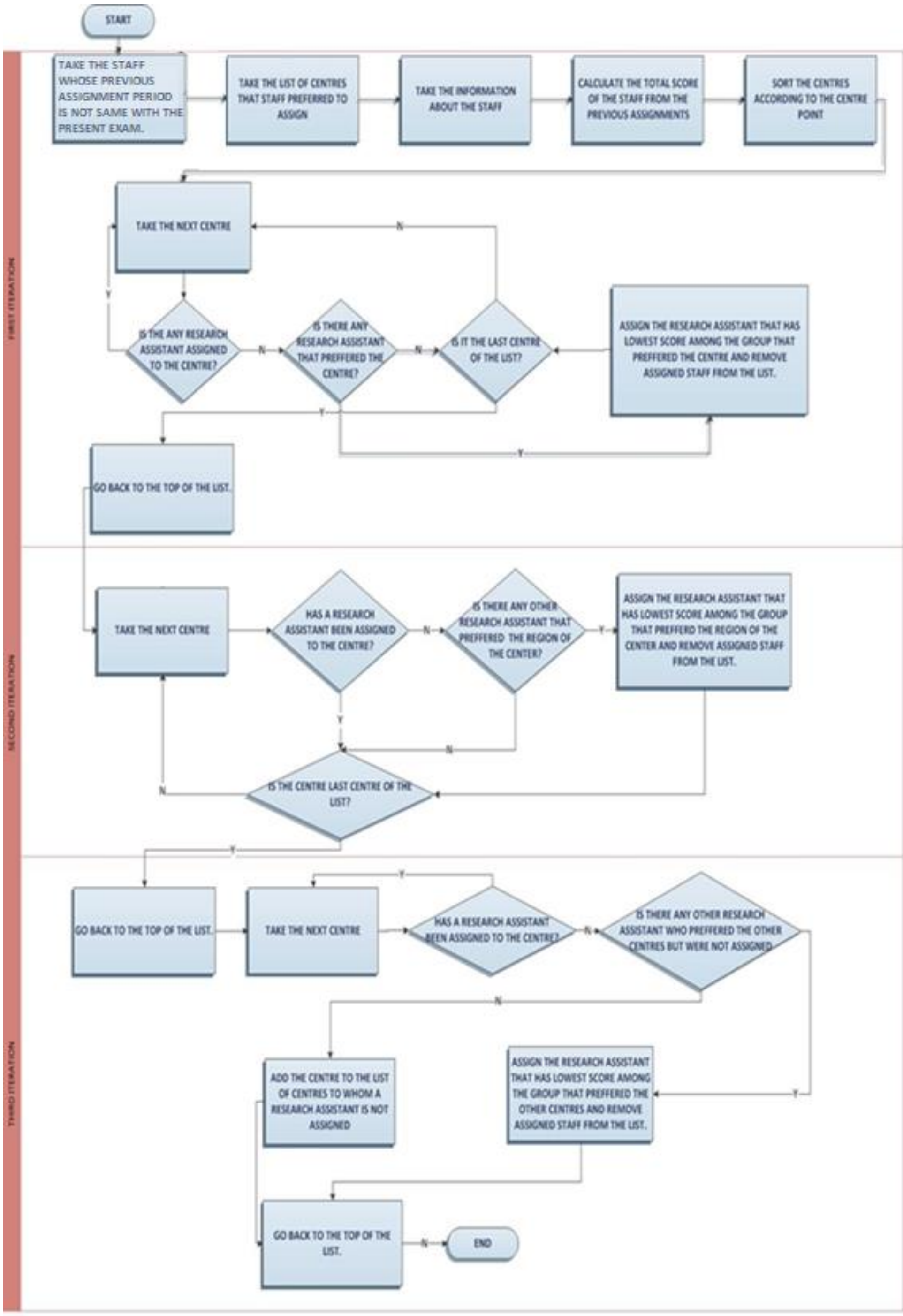


Fig. 4. Find an invigilator Who are a Research Assistant

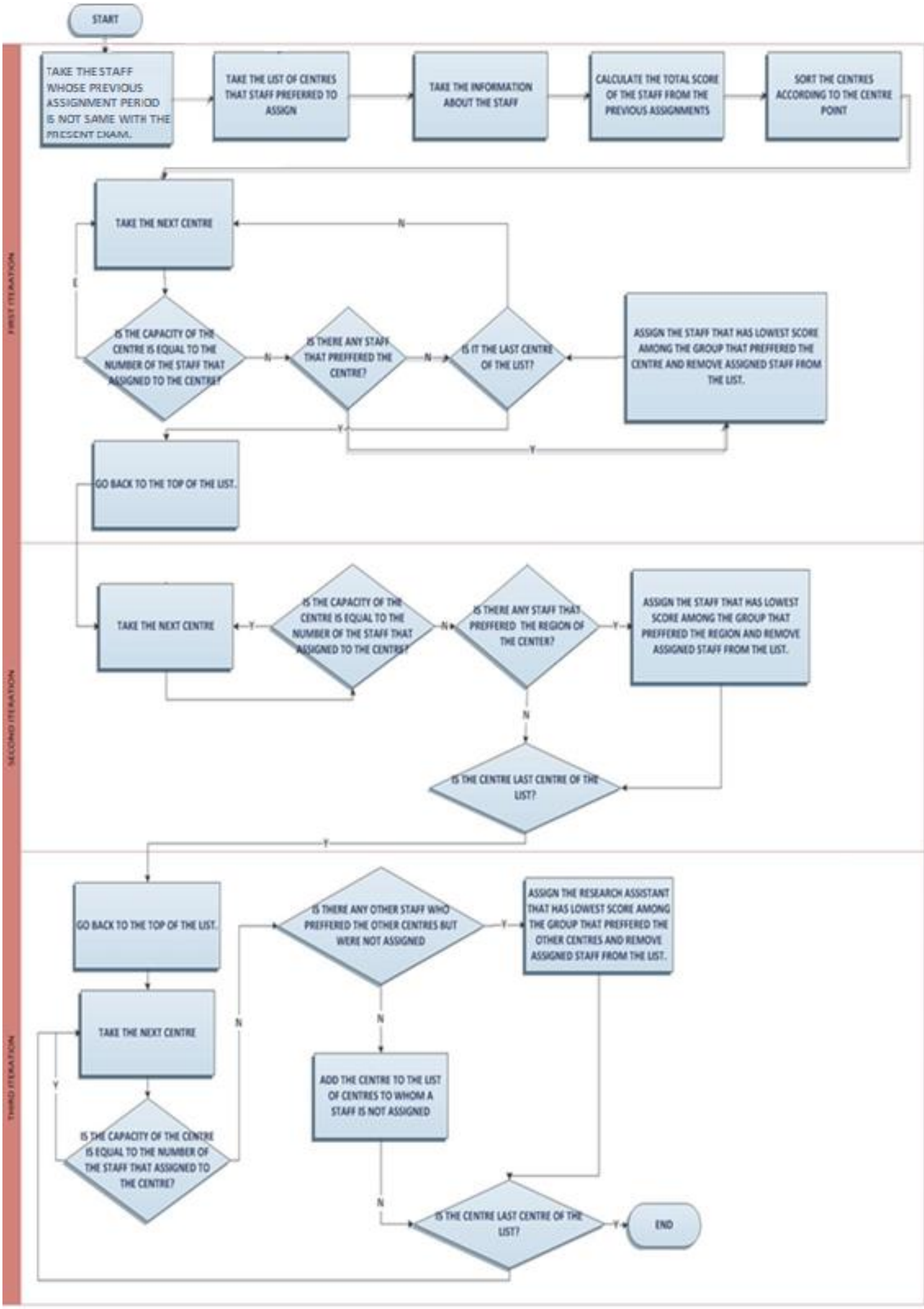


Fig. 5. Find an invigilator to the centers

## 3. RESULTS AND DISCUSSIONS

The assignment software was developed in the C# language in accordance with the algorithm. Thus, the result of the problem is directly linked to the preferences of the invigilator, and different preference scenarios are developed and the model was run again for these new situations. The profile of each invigilator member is simulated using three choices and these three choices are randomly created. While creating the choices for the centers, the information regarding which invigilators were assigned previously is removed from the pool. The total score of each member of invigilators is calculated with the data from previous assignments. In the first scenario, when the invigilator prefers three centers from three different center groups, whereas in the second, an invigilator selects two centers from three different groups. In the third scenario, the invigilator selects six centers from three different groups. The evaluation of the assignment is shown in Table 1.

Table 1. Assignment Evaluation Data

| | The Number of Assigned) Invigilator | The Number of invigilator assigned to their Preference | The Rate of Assignment to Preferences |
|---|---|---|---|
| Scenario 1 | 379 | 326 | 0,86 |
| Scenario 2 | 379 | 362 | 0,97 |
| Scenario 3 | 379 | 379 | 1 |

In the first scenario, there are 379 invigilators was assigned to the centers and 326 of these invigilators were assigned to their preferred centers. In the second scenario, 362 of 379 invigilators was assigned to their preferred centers. And in the third scenario, all of the 379 invigilators was assigned to their preferred center.

## 4. CONCLUSION

In this study, an invigilator assignment for an open distance education exam problem was examined as a real-life problem. The invigilator assignment operations were taken as a whole, and the whole process was then revised. After reviewing the process flow, the assignment problems in the literature were revised, and the problem was resolved to be an assignment problem. The mathematical model was proposed to solve our problem. An algorithm was designed and coded with C# to ensure that end users could use the model actively. The current invigilator assignment system that used in the university has some problems, such as the time and manpower needed to perform the assignment, difficulty in evaluating the preferences of invigilators, failure to equitably assignment of invigilators, and inability to follow changes in the system.

The prepared system assigns the invigilators to the appropriate centers taking account of the constraints and past scores. Minimizing the total scores of the assigned invigilator was considered as the success criterion of the assignment. The program was operated according to different preferred scenarios and the following results were obtained. Making an informed choice seems to play an important rate in increasing the success rate. In order to increase the success rate, the invigilator should be informed about their overall scores while expressing their preferences. The output of the developed program varies according to the sorting list of examination centers. Assignments were made by using 1000 different sets where the centers are listed. Sorting was created by different methods, which selected the best results out of this assignment. In future studies, different sorting techniques could be studied to achieve best results.

The developed system has shown a significant success in terms of time efficiency. The final cut of the developed system takes a period of approximately three minutes to run. With this program, assignment process time has been reduced from weeks to minutes. Before using this program, the preferences of the invigilator were not taken into consideration. While some of the invigilators were assigned to the same centers in all exams, the other invigilator could not have assigned in any exam. The use of this program brought a fair assignment system.

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