

Seat Assignment Model for Student Admissions Process at Saudi Higher Education Institutions

Mohammed Salem Alzahrani

Abstract—In this paper, student admission process is studied to optimize the assignment of vacant seats with three main objectives. Utilizing all vacant seats, satisfying all programs of study admission requirements and maintaining fairness among all candidates are the three main objectives of the optimization model. Seat Assignment Method (SAM) is used to build the model and solve the optimization problem with help of Northwest Corner Method and Least Cost Method. A closed formula is derived for applying the priority of assigning seat to candidate based on SAM.

Keywords—Admission Process Model, Assignment Problem, Hungarian Method, Least Cost Method, Northwest Corner Method, Seat Assignment Method (SAM).

I. INTRODUCTION

SEAT assignment optimization for admission process is always one the most significant challenges for any educational institution specifically for admissions departments. Many factors are involved to come up with a certain figure for the optimal number of available seats for upcoming new students. In addition to that, the educational institution must assure and study the risk of student's outflow that happens from the time of application until semester withdrew deadline time.

In Saudi Arabia, more than 25 governmental universities [12] and 36 governmental technical colleges are offering variety of major studies all over KSA [3]. All Saudi students are able to choose their preferred field of study with no study tuition if they fulfill the admission requirements. As of 2014, Saudi Arabian higher education institutions have 4,137 academic programs [2]. For 2014-2015, Ministry of Higher Education (MOHE) in Saudi Arabia offered 349,186 seats for new students joining more than 25 universities all over the country [11]. That number of available seats is only for KSA universities without declaring the other ways of getting free higher education like:

1. King Abdullah Scholarships Program (KASP)
2. Technical & Vocational Training Corporation (TVTC)
3. Military Colleges

However, some major fields of studies have limited seat capacity like health and engineering fields. Fairness in assigning seat to a student is the absolute main goal to those educational institutions.

To assign seats to students and keep up the fairness flagged and considered, seat assignment method (SAM) is suggested

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to play the role in solving the problem of seat assignment [4]. SAM is the new method of assigning seats and built particularly to solve the problem of admission's process for seat assignment. The other assignment problem methods like *Hungarian*, *Northwest Corner*, *Least Cost* and *Work Station Assignment Problem* are giving a solution to the problem but they will not grantee fairness to candidate students [1], [5]-[8]. Some other solutions, which are offered by industrial experts, are adjustable for some manufacturing processes like Flexible Manufacturing System (FMS) [9]. Moreover, methods such as *QuickMach* [10] are built to solve linear assignment problems.

In this paper, the seat assignment problem is solved using SAM. The model is built and described in two subsections: model setup and model readings.

II. MODEL DESCRIPTION

A. Model Setup

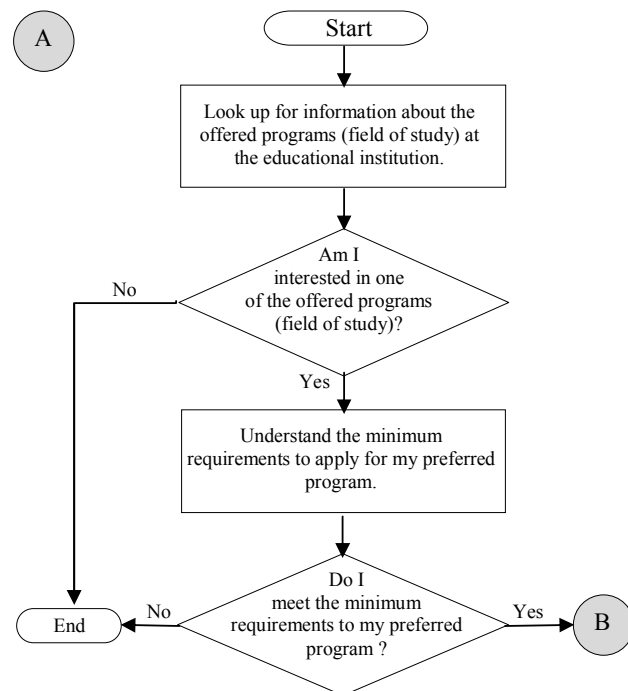


Fig. 1 Admission System Process (Candidate Prospect)

SAM's model is a part of admission process in which the process is optimized. For a general overview of the admission system process, two sides are viewing the process; from the side of applying candidate student (user) and the other side is the university or admission department (process owner). In

general, new student who is planning to apply for a specific program (field of study) in one of KSA universities has a systematic plan and responsibilities for admission process flow as shown through Fig. 1.

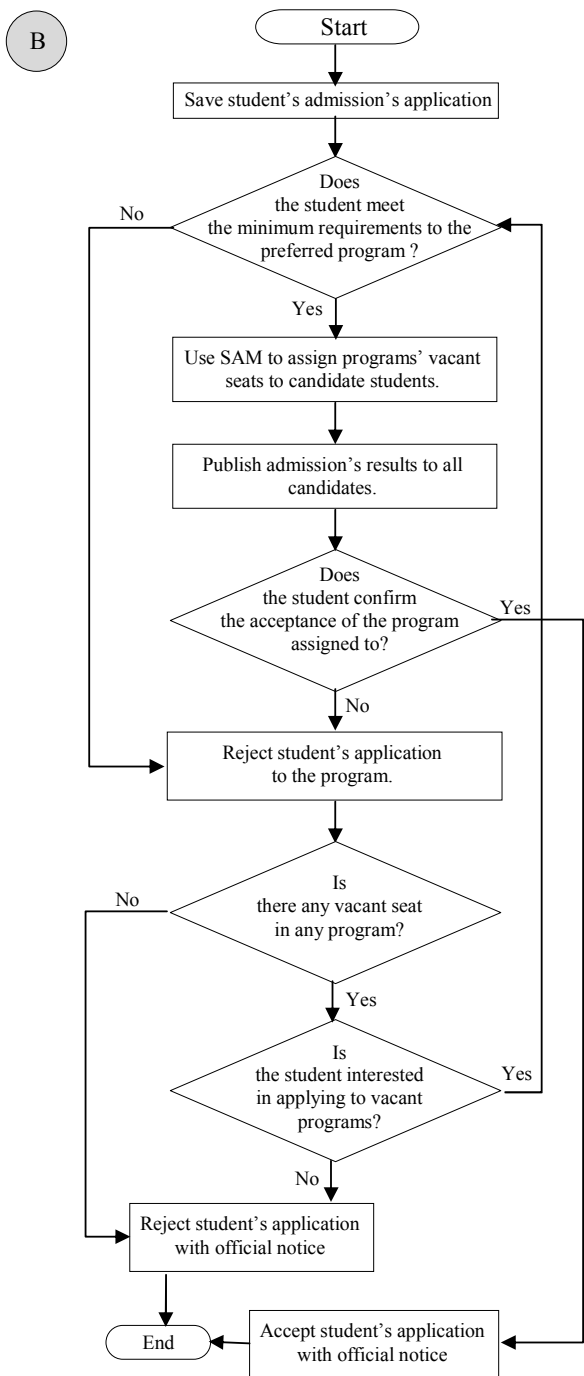


Fig. 2 Admission System Process (University Prospect)

However, the educational institution is involved on that processes with hidden tasks such as, preparing the information details for each offered program with its admission

requirements and its essential related information like future job nature and market demand for that program in the next few years. On the other hand, the part of admission process, in which the university holds countable for, starts from the stage of receiving student application as shown in Fig. 2.

This suggested model for admission process of seat assignment optimization is applicable and feasible in the following cases:

1. The number of applicants is more than 100 students.
2. The number of major field of studies (academic programs) is more than 4 programs.
3. Number of offered seats is more than 100 seats.
4. The final decision of acceptance depends on qualifying exams' grades.
5. The final decision of acceptance does not depend on subjective opinion such as interview.
6. If the final decision of acceptance depends on program's department or college interviews, then this model can be used as final decision to include the candidate in an interview-closed list.

SAM's model has the following inputs:

- F_j : is the j^{th} field of study which any student can apply to.
- sTi : is the i^{th} candidate of students.
- m : is the total number of major fields of study (programs).
- n : is the total number of candidates (students).
- N : is the total number of required seats.
- P_{ij} : is the preference rank for i^{th} candidate to j^{th} field of study.
- A_j : is the number of seats available in the j^{th} field of study

The model shows that educational institution is offering m different major programs (field of study) with capacity of A_j seats for j^{th} field. It can accept up-to n applying students who can express their preference for the offered program by raking their preference where 1 goes for the most desirable program to the candidate and m goes for the most undesirable program. In plan tableau, preference for all candidates can be expressed as shown in Table I with a condition of balanced problem where number of available seats is equal to number of required seats:

TABLE I
REFERENCE MATRIX

| Field | F_1 | F_2 | ... | F_j | ... | F_m | Required Seats |
|-----------------|----------|----------|----------|----------|----------|----------|----------------|
| sT_1 | P_{11} | P_{12} | ... | P_{1j} | ... | P_{1m} | l |
| \vdots | \vdots | \vdots | \ddots | \vdots | \ddots | \vdots | \vdots |
| sT_i | P_{i1} | P_{i2} | ... | P_{ij} | ... | P_{im} | l |
| \vdots | \vdots | \vdots | \ddots | \vdots | \ddots | \vdots | \vdots |
| sT_n | P_{n1} | P_{n2} | ... | P_{nj} | ... | P_{nm} | l |
| Available Seats | A_1 | A_2 | ... | A_j | ... | A_m | N |

The educational institution receives and saves candidates' application information along with their preferences. The next stage of admission process done by the educational institution is ranking candidates according to their qualifying exams results. The qualifying exams results in KSA universities are calculated using the following formula:

$$Q = \alpha X + \beta Y + \gamma G + \vartheta Z \tag{1}$$

where main variables are:

- Q : Total qualifying exams (TQE) grade points.
 - X : High school cumulative grade points average (GPA).
 - Y : General aptitude test (GAT) exam grade.
 - G : Educational achievement test (EAT) exam grade.
 - Z : Admission interview assessment (AIA) grade.
- and their associated coefficients are:
- α : Wight factor assigned to GPA.
 - β : Wight factor assigned to GAT.
 - γ : Wight factor assigned to EAT.
 - ϑ : Wight factor assigned to AIA.

Each educational institution has its identifiable weight to each factor with the following weight constraint:

$$\alpha + \beta + \gamma + \vartheta = 1 \tag{2}$$

In case of admission interview is not a part of the admission process to the program then the value of ϑ is zero and so on for all factors related to GPA, GAT and EAT. Not all KSA universities put a minimum grade for GPA, GAT, EAT or AIA. In general, lower bounds for grades are expressed as grades lower limits constraints:

$$X > x \tag{3}$$

$$Y > y \tag{4}$$

$$G > g \tag{5}$$

$$Z > z \tag{6}$$

In addition to that, some universities add one more constraint for TQE as lower limit constraint:

$$Q > q \tag{7}$$

B. Model Readings

The optimization model is built using SAM, which enables clients to read easily candidates' major programs preferences tendency and gives main descriptive statistics. To enable SAM produces such readings; it must be set-up and build the preference matrix after ranking all candidates from highest to lowest according to their TQE. Taking in consideration that the model data for the preference matrix is ordinal data, the model is able to show the following readings:

1. The Most Desirable Field of Study

The most *desirable* field of study is the *maximum* value of $(\sum_{i=1}^{i=n} P_{ij}$ for all $P_{ij} = 1$ where $j = 1, 2, \dots, m$).

2. The Most Undesirable Field of Study

The most *undesirable* field of study is the *maximum* value of $(\sum_{i=1}^{i=n} P_{ij}$ for all $P_{ij} = m$ where $j = 1, 2, \dots, m$).

3. The Most Desirable and Undesirable Field of Study

The same field of study can be both most desirable and undesirable when both above cases (1 and 2) are true.

4. The Mean of the Preference Data Matrix

For each candidate, m choices are available and they have to be ranked from 1 to m then:

$$sT_i \begin{bmatrix} F_1 & F_2 & \dots & F_j & \dots & F_m \\ P_{i1} & P_{i2} & \dots & P_{ij} & \dots & P_{im} \end{bmatrix}$$

$\sum_{j=1}^m P_{ij} = \sum_{j=1}^m j$ has always the same value for all $i = 1, 2, \dots, n$ which is used to find the total sum of the preference matrix elements using:

$$\sum_{i=1}^n \sum_{j=1}^m P_{ij} = \sum_{i=1}^n \sum_{j=1}^m j = n \times \sum_{j=1}^m j \tag{8}$$

Using the previous fact to help find the preference matrix mean:

$$Mean = \frac{\sum_{i=1}^n \sum_{j=1}^m P_{ij}}{n \times m} \rightarrow \frac{n \times \sum_{j=1}^m j}{n \times m} = \frac{\sum_{j=1}^m j}{m} \tag{9}$$

5. The Median of the Preference Data Matrix

Finding the median requires rearranging the preference matrix in ascending order for the field of study row then the new preference matrix tableau updated as shown in Table II.

TABLE II
REFERENCE MATRIX SORTED IN ASCENDING ORDER

| | | | | | | |
|----------|----------|----------|----------|----------|----------|----------|
| sT_1 | 1 | 2 | ... | J | ... | m |
| sT_2 | 1 | 2 | ... | J | ... | m |
| \vdots | \vdots | \vdots | \ddots | \vdots | \ddots | \vdots |
| sT_i | 1 | 2 | ... | J | ... | m |
| \vdots | \vdots | \vdots | \ddots | \vdots | \ddots | \vdots |
| sT_n | 1 | 2 | ... | J | ... | m |

It can be illustrated as non-matrix form:

$$\underbrace{1, 1, \dots}_n, \underbrace{2, 2, \dots}_n, \dots, \underbrace{\dots, \dots}_n, \underbrace{j, j, \dots}_n, \dots, \underbrace{\dots, \dots}_n, \underbrace{m, m, \dots}_n$$

Since the model is holding up-to n candidates, then each candidate has m programs to choose from which results in repetition of n selections to each program. As a result of that fact, finding the median for one candidate is exactly as finding the median for the whole preference matrix. Therefore, the median as defined is the middle element of $1, 2, \dots, j, \dots, m$ holding the fact that the preference matrix elements is incremental by one with no repeating for the same candidate (row wise), then m is the total number of elements in the row.

$$Median = \frac{m+1}{2} \tag{10}$$

is valid for both numbers of elements even and odd.

6. The Mean and Median of the Preference Data Matrix Are Equal

The relationship between mean and median of the preference matrix is proven mathematically that they are equal, starting with (9) reaching (10). Where $\sum_{j=1}^m j$ is known as the m^{th} partial sum of a triangle series that has m terms and total sum of $\frac{m \times (m+1)}{2}$. By substituting the m^{th} partial sum of the

triangle series that has a sum of $\frac{m \times (m+1)}{2}$ into the main formula for the mean we get

$$mean = \frac{m \times (m+1)}{2 \times m} = \frac{m+1}{2} = median \quad (11)$$

III. SOLVING THE ASSIGNMENT PROBLEM USING SAM

To set-up the model, the preference matrix has to be ready as done in the previous section of model setup. In order to derive the optimal solution according to the intended problem with keeping the fairness as the main concern, the solution must be presented in a matrix called result matrix in which R_{ij} is the element that has the values 1 or 0. R_{ij} carries the value of 1 if the i^{th} candidate is assigned to j^{th} seat otherwise it carries the value of 0.

TABLE III
RESULT MATRIX

| Field | F_1 | F_2 | ... | F_j | ... | F_m | Required Seats |
|-----------------|----------|----------|-----|----------|-----|----------|----------------|
| sT_1 | R_{11} | R_{12} | ... | R_{1j} | ... | R_{1m} | 1 |
| sT_2 | R_{21} | R_{22} | ... | R_{2j} | ... | R_{2m} | 1 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| sT_i | R_{i1} | R_{i2} | ... | R_{ij} | ... | R_{im} | 1 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| sT_n | R_{n1} | R_{n2} | ... | R_{nj} | ... | R_{nm} | 1 |
| Available Seats | A_1 | A_2 | ... | A_j | ... | A_m | n |

After setting up model's preference matrix, SAM uses northwest corner element of the preference matrix to start with and then do the following:

1. Determine capacity for the j^{th} field = A_j for all $j = 1$ to m
2. Initialize $R_{ij} = 0$ for all i and j .
3. Set $i = 1, j = 1$ and go to 9
4. Update $i = i + 1$
5. If $i > n$, go to 13
6. Set $j = 1$ and go to 9
7. Update $j = j + 1$
8. If $j > m$, go to 4
9. Is P_{ij} the minimum value row wise in the preference matrix? If yes go to 10, if no go to 7.
10. Is $A_j > 0$, If yes go to 11, if no go to 7 (seat availability constraint)
11. $A_j = A_j - 1$
12. Update $R_{ij} = 1$ and go to 4
13. End

At this stage, the *Least Cost Method* (LCM) is used with modification within SAM's closed formula. LCM makes use of the cost value to give priority value to each candidate. On the other hand, SAM gives intelligently more priority of fairness by creating a formula for cost that deals with three main parts

1. Seat field priority P_{ij} that is the preference rank for i^{th} candidate to j^{th} field of study.
2. Number of field of studies (academic programs) m .
3. Number of seats available in the j^{th} field of study A_j .

After sorting and ranking candidate students from highest to lowest order according their QTE, SAM's main tableau is

built as shown in Table IV.

TABLE IV
FORMATTED SAM'S TABLEAU

| Field | F_1 | F_2 | ... | F_j | ... | F_m | Required Seats |
|-----------------|--------------------------|--------------------------|-----|--------------------------|-----|--------------------------|----------------|
| sT_1 | P_{11} C_{11} 1 1 | P_{12} C_{12} 1 2 | ... | P_{1j} C_{1j} 1 j | ... | P_{1m} C_{1m} 1 m | 1 |
| sT_2 | P_{21} C_{21} 2 1 | P_{22} C_{22} 2 2 | ... | P_{2j} C_{2j} 2 j | ... | P_{2m} C_{2m} 2 m | 1 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| sT_i | P_{i1} C_{i1} i 1 | P_{i2} C_{i2} i 2 | ... | P_{ij} C_{ij} i j | ... | P_{im} C_{im} i m | 1 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| sT_n | P_{n1} C_{n1} n 1 | P_{n2} C_{n2} n 2 | ... | P_{nj} C_{nj} n j | ... | P_{nm} C_{nm} n m | 1 |
| Available Seats | A_1 | A_2 | ... | A_j | ... | A_m | n |

From this stage and after, LCM is used to solve the seat assignment problem containing the closed new formula for SAM that defines its main new finding:

$$C_{ij} = P_{ij} + m \times (i - 1) \quad (12)$$

SAM with its new closed formula for C_{ij} gives assurance of fairness in program's seats assignment to students.

Student outflow during and after the admission process is huge burden for Saudi institutions. Variety of choices for free higher education programs gives the student the ability to reject the offered program during the admission process. That action from students creates new vacant seats at every run for the admission process. Therefore, the institution makes the admission process run more than once or it makes it go back to manual admission process instead of automated run as shown in Fig. 3.

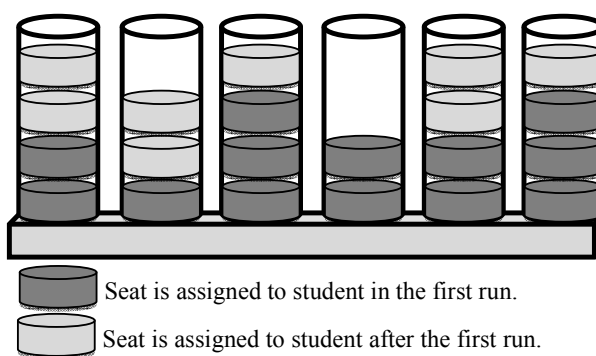


Fig. 3 Case of Running Admission process more than once

A solution will be suggested to the above issue in upcoming research, which will concentrate on running SAM using software coding that runs every single time if there is a vacant seat for admission.

IV.CONCLUSION

Seat assignment optimization for admission process at Saudi higher education institutions is studied with main goal of keeping fairness aspect. SAM is used to build model and solve the issue to serve its main purpose of fairness. *Northwest Corner* and *Least Cost Methods* are used implicitly to build and solve SAM's model. The mathematical approach used in SAM can solve seat assignment problem for student admission's process efficiently and serves the main goal of fairness maintaining.

REFERENCES

- [1] A Fast, Near Optimal Heuristic for the Work Station Assignment Problem, Candance Aral Yano.
- [2] Alangary, A. (2014). Academic Programs Guide Book for Saudi Arabia Higher Education Institutions (3rd Edition), Riyadh: Ministry of Higher Education in Saudi Arabia.
- [3] Alhaidar, M. (2013). Opening 7 New Branches for Technical Colleges this Year All Over Kingdom. Issue 16505. Retrieved 05-Jul-2014, 2014, from <http://www.alriyadh.com/863867>
- [4] Alzahrani, M. (2013). 'Seat Assignment Problem Optimization'. World Academy of Science, Engineering and Technology, International Science Index 77, 7(5), 441 - 444.
- [5] Applied Management Science: Modeling, Spreadsheet Analysis, and Communication for Decision Making, 2nd Edition, John A. Lawrence, Barry A. Pasternack.
- [6] Managerial Decision Modeling with Spreadsheets (2nd Edition), Nagraj Balakrishnan (Author), Barry Render (Author), Ralph M. Stair (Author).
- [7] Operations Research: An Introduction (9th Edition), Hamdy A. Taha
- [8] Operations Research Applications and Algorithms (4th Edition), Wayne Winston, 2003.
- [9] Operations Research: Methods, Models, and Applications, Jay E Aronson, Stanley Zionts.
- [10] Orlin, James B., 1953- & Lee, Yusin., 1993. "QuickMatch - a very fast algorithm for the assignment problem," Working papers 3547-93., Massachusetts Institute of Technology (MIT), Sloan School of Management.
- [11] Saudi Arabia Ministry of Higher Education. (2014). Retrieved July 06, 2014, from <http://www.mohe.gov.sa/ar/AcceptedStatus/Pages/default.aspx>
- [12] Saudi Arabia Ministry of Higher Education. (2014). Retrieved July 07, 2014, from <http://www.mohe.gov.sa/ar/studyinside/Government-Universities/Pages/default.aspx>