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PROGRAM ALLOCATION PROCESS IMPROVEMENT BY AN ASSIGNMENT MODEL

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ABSTRACT

As the only source of jet pilot candidates for Turkish Air Force, Air Force Academy (TuAFA) applies several screening processes in order to acquire an average group of 150 cadets from civilian high school graduates each year. Besides the nationwide examinations (YGS-LYS), there are several others such as medical, flight, athletics evaluations and etc. Because the number of criteria for screening is large, the spread of the distribution of YGS-LYS scores of the candidates, which is assumed to be the aptitude towards college education, is a lot wider than those of other universities. Although admission to faculty for civilian high school students is regulated by the YGS-LYS score; in order to provide a balance distribution among different programs in terms of YGS-LYS score, placement to aerospace, electronics, computer and Industrial engineering programs of the Faculty is governed by a special directive. Although the directive considers candidates' preferences, the ultimate goal of the algorithm in the directive is to keep the balance of academic success among different programs in the allocation process. In this study, we propose an alternative assignment model which tries to minimize the deviations from students' preferences while maintaining the balance of the distribution among programs. Through simulation from different preference distributions with different number of students, it has been showed that regardless of the number of students and distribution of preferences,first choice allocation performance of the proposed model is significantly better than the directive's algorithm.

Keywords**:** *Balanced Assignment Problem, Process Improvement, Stable Marriage Problem.*

HHO BÖLÜMLERE AYIRMA SÜRECİNİN ATAMA MODELİYLE İYİLEŞTİRİLMESİ

ÖZET

Türk Hava Kuvvetlerinin pilot adaylarının yetiştiği tek kurum olan Hava Harp Okulu (HHO), her yıl, bünyesinde eğitim vereceği sivil lise mezunu yaklaşık 150 öğrenciyi seçebilmek amacıyla, ülke çapında uygulanan YGS-LGS sınavlarına ek olarak uçuş, spor, sağlık ve psikomotor gibi çok sayıda eleme aşaması uygulamaktadır. Bunun nedeni HHO'nun öğrencilerinde akademik beceriler yanında liderlik becerileri de araması, mezunlarına hem mühendislik hem de subaylık diploması vermesi, daha da önemlisi, 4 yıllık eğitim-öğretim dönemi sonunda pilot adayı olarak mezun olabilenlerin son teknoloji ile donatılmış süpersonik uçaklara kumanda etmesidir. Ek olarak, HHO mezunları, NATO üyesi seçkin bir hava kuvvetinde kariyer yapabilme garantisi elde etmektedir. Öğrenci alımlarında seçim kriteri sayısının fazla olması nedeniyle, adayların üniversite öğrenimine hazır bulunuşluklarının bir göstergesi olan YGS-LGS puanının dağılımının varyansı, diğer üniversite bölümlerinin varyansından daha büyüktür. Bu yüzden öğrencilerin HHO Dekanlığı bünyesindeki 4 farklı mühendislik bölümüne ayrılmaları, özel bir yönergeyle düzenlenmiştir. Yönerge, adayların tercihlerini dikkate almakla birlikte asıl amaç, bölümler arası akademik başarıyı dengeli dağıtmaktır. Bu çalışmada, bölümlere ayırma sürecinde öğrencinin ilk tercihinden sapmaları minimize eden ve aynı zamanda bölümler arası dengeyi de sağlayan alternatif bir atama modeli önerilmiştir. Önerilen modelin ilk tercihe yerleştirme performansının, yönergedeki algoritmadan anlamlı şekilde üstün olduğu ve bu üstünlüğün öğrenci sayısından ve tercih dağılımından bağımsız olduğu, farklı tercih dağılımlarından yaratılan benzetim verileriyle gösterilmiştir.

Anahtar Kelimeler**:** Dengeli Atama Modeli, Süreç İyileştirme, Dengeli Evlilik Problemi (Stable Marriage Problem, SPA).

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1. INTRODUCTION

Graduation from a reputable university is assumed to be the key to succeed in life. On the other hand, in most of the developing countries, competition is fierce because the number of seats is disproportionally scarce against the population of students. In Turkey, match between the students and the programs is basically determined via the national exams, LGS (Transition to Higher Education Examination) and LYS (Undergraduate Placement Examination). In 2013, 38.2% of the students who passed the pre-elimination exam LGS and had the right to choose a program, did not attempt to do so, because they were sure that their combined score (40%LGS+60%LYS) would not allow them to get a seat in their order of preference. Hence they kept their position instead of making a choice in vain.

To our knowledge, there has been little quantitative research on LYS type placement exams in terms of the match between student preference and the overall value to society. It is assumed that a student who is placed to the first program in his/her order of preference will be more successful or willing to do so during his/her entire career. As an example in Turkey, after the announcement of combined YGS-LYS scores, students are allowed to choose 30 alternative programs to form their order of preference. They usually sort the programs on the basis of previous years' ground scores. The allocation is simple; the one who has higher score is more likely to place to his/her first slot in the preference list. However due to the time limit and waste number of programs, student choices and the resulting placement are subject to discussion. Most of the students choose programs thinking of theirself-economic interest or career, some for academic interest and some just follow the crowd. There is no concern about the demand in the economy or the overall welfare of the society. As a result, intellectual capital distribution is not balanced, leaving some economic segments underdeveloped and some skyrocketed.

College admission problem can be modeled as an assignment problem, where students and universities have preferences over each other. In the literature [1-4], assignment problem where two sets of elements given a set of preferences for each element, known as the *stable marriage problem (SMP)*. A matching is a mapping from the elements of one set to the elements of the other set. A matching is stable whenever it is not the case that both:

- Some given element A of the first matched set prefers some given element B of the second matched set over the element to which A is already matched, and
- B also prefers A over the element to which B is already matched.

In other words, a matching is stable when there does not exist any alternative pairing (A, B) in which both A and B are individually better off than they would be with the element to which they are currently matched. Hospital/residence problem is a special case of SMP, – also known as the college admissions problem – differs from the stable marriage problem in that the "women" can accept "proposals" from more than one "man" (e.g., a hospital can take multiple residents, or a college can take an incoming class of more than one student). Algorithms to solve the college admissions problem can be college-oriented (female-optimal) or student-oriented (male-optimal).

In [1], it has been proved that, for any equal number of men and women, it is always possible to solve the SMP and make all marriages stable. However, stability does not necessarily mean optimality. In [4], it has been shown that finding a maximum stable matching for the problem of allocating students to projects, where both students and lecturers have preferences over projects, and both projects and lecturers have capacities is NP-hard. Therefore, many of the literature focus on approximation algorithms [5].

Program placement problem discussed here is similar to college admissions problem where programs establish priorities according to students' combined academic score and students' preferences can follow arbitrary distributions.We applied the proposed method to TuAFA's Faculty which has four different programs.

This paper consists of five sections. Section 1 is the introduction, in section 2 TuAFA's current placement algorithm is presented, which is followed by the proposed assignment model in Section 3. Section 4 reserved for the empirical findings of our model and finallythe concluding remarks provided in Section 5.

2. TuAFA PROGRAM PLACEMENT ALGORITHM

In order to overcome the problem of uneven distribution of intellectual capital among different programs, Turkish Air Force Academy (TuAFA) follows a different placement strategy for its programs. Applying to the Turkish Air Force Academy (TuAFA) is considerably more involved than applying to a typical university in Turkey. There are many steps and challenges an applicant must meet. TuAFA seeks individuals who possess good academic skills besides leadership potential. This is because TuAFA offers both university degree and officer diploma for its graduates, and more importantly, at the end of the 4 year education, those who are qualified as a jet pilot candidate can fly supersonic aircraft equipped with cutting edge technology. Moreover, a life time career is guaranteed in one of the World's distinguished NATO allied air force.

Because of its unique offerings and intense evaluation strategy, the number of applicants for TuAFA's freshman class pools an average of 6,000 high school graduates to enroll only 150 cadets each year. As a result, the spread of the distribution of YGS-LYS score of the applicants is wider than those of similar colleges in Turkey, but representative of the initial pool. TuAFA Faculty has four alternative engineering programs namely, Aerospace (AE), Electronics (EE), Computer (CE) and Industrial Engineering (IE). A poorly administered program allocation in a boarding school, may result undesirable preference information, in a sense all the students follow the same preference structure which makes it hard to find a compromise between programs' quota and student preferences. Because they would basically sort programs depending on the previous year's graduation rate, follow the leader, or word of mouth.

Current program placement algorithmis presented below:

1. Record candidates' order of preference in order from most to least preferable,
2. Sort candidates descending order according to academic score and split them into groups according to class requirement,
3. Take the first group and place the first candidate to his/her first choice,
4. Place the next candidate according to his/her order of preference if it is not occupied by the previous,
5. Go to step 4 until all candidates placed.

Advantage of the above placement algorithm is, academic scores or intellectual capital will definitely be distributed evenly among programs but also within variance of the programs will almost be equal. However, a candidate who has higher score can be placed to the last spot in his/her preference list. For example, if there exist 8 classes and 2 classes for each program, according to academic score 8^{th} candidate can be placed to his 4^{th} preference, while 121^{st} student will be placed to his/her first preference. This is not fair and penalizes successful candidates. The question is can there be any other approach satisfying distributional constraints and also reasonable for diligent students. In other words, the outcome is female-optimal and in the next section we propose an alternative assignment model, where the student preferences are considered and Pareto optimality can be achieved.

3. PROPOSED ASSIGNMENT MODEL

In order to provide a compromising solution for all stakeholders, a preference score, p which is a measure of candidate's disappointment is introduced to penalize deviations from candidate's first preference. Let

Sets:

R Set of programs, $\{CE, EE, IE, AE\}$
p_{ij} ith candidate's preference score for jth program, $\forall p \in \{0, 1, 2, 3\}$, $\forall i \in \{1, 2, 3, \dots, n\} \forall j \in R$ where n is the number of candidates. If ith candidate has a preference score array {1, 3, 2, 0}, his order of preference is actually *AE pCE pIE p EE*. His/her first choice is *AE*, then *CE*, then *IE* and then *EE*. We checked that the solution is not sensitive to different choices of values for p:

Parameters:

s_i ith candidate's combined academic score,
b_j jth program's quota,
a average academic score of all candidates, $a = \frac{\sum_i^n s_i}{n}$

Variables:

A binary variable is used if ith candidate assigned to his/her jth preference,

$$y_{ij} = \begin{cases} 1, & \text{if } i\text{th candidate assigned to } j\text{th program} \\ 0, & \text{otherwise,} \end{cases}$$

$\varepsilon_j^-, \varepsilon_j^+$ deviations of average academic score of jth program from a

The objective function is:

$$Min\ Z = (f, \varepsilon_j^-, \varepsilon_j^+) \quad (1)$$

Minimizing f, which is a measure of total disappointment weighted by the academic score of candidates, will move the search process towards candidates' first preferences, while minimizing ε_j^- and ε_j^+, will provide a balanced academic success distribution among programs.

Subject to:

$$f = \sum_{i=1}^{n} \sum_{j=1}^{4} s_i p_{ij} y_{ij} \quad (2)$$

Average academic score for jth program is:

$$\frac{\sum_{i=1}^{n} y_{ij} s_i}{b_j} + \varepsilon_j^- - \varepsilon_j^+ = a \quad (3)$$

The programs'quotas must be met:

$$\sum_{i=1}^{n} y_{ij} = b_j \qquad (4)$$

Each candidate must be assigned to exactly one program:

$$\sum_{j=1}^{4} y_{ij} = 1, \qquad (5)$$

$y_{ij} = 0$ or 1, $\varepsilon_j^-, \varepsilon_j^+ \geq 0$

IBM ILOG CPLEX optimization software is used to run above model for different data sets. The results are summarized in the next section.

4. EMPIRICAL FINDINGS

The proposed multi-objective model is applied to 137 candidates who applied in 2012fall admission period. Next, in order to generalize the performance of the model, same number of candidates with same preference distribution is generated. Then to see the effect of number of students and preference distribution, 250 students from uniform and skewed preference distributions are generated.Academic scores are also generated and assigned to students from the normal distribution with mean 53.21 and standard deviation 18.98, as 2012 fall semester. Program placement results of the proposed model and the directive's algorithm are compared on the basis of disappointment metric.

In Figure 1, comparison of proposed model and the directive's algorithm is presented for 2012 fall semester. The proposed model placed significantly more students to his/her first preference than the directive. Moreover unlike the directive, no students placed to his/her last preference. In disappointment scale, the proposed model produced 62% less disappointment than the directive. The mean academic score of the programs are almost equal. ANOVA in Table 1, showing the mean scores according to proposed model placement, revealed no significant differences among programs.

In Figure 2, the distribution of preference listings is presented for 2012 fall semester. Here, horizontal axis represents students' order of preference in descending order and vertical axis represents frequency of the students who picked that preference. For example, first column in the graph represents 16 students who picked {3, 1, 0, 2} order (*IE, EE, AE, CE*).

Despite some preference listings highly cited than others, all possible permutations are recorded by the students. For 4 programs, 4! = 24 different preference listings are possible. In order to generalize the results for the proposed model, 10 different data sets are generated from the same distribution for 137 cadets and results are tabulated in Table 2. On the average, the proposed model produces 67% less disappointment than the directive's algorithm.

The performance of the proposed method can change depending on the distribution of cadets' preferences. We expect similar results with uniform or almost uniform preference distributions. 10 data sets each having 250 cadets with equally likely preference listings are generated. The results of both methods in disappointment metric are tabulated in Table 3.

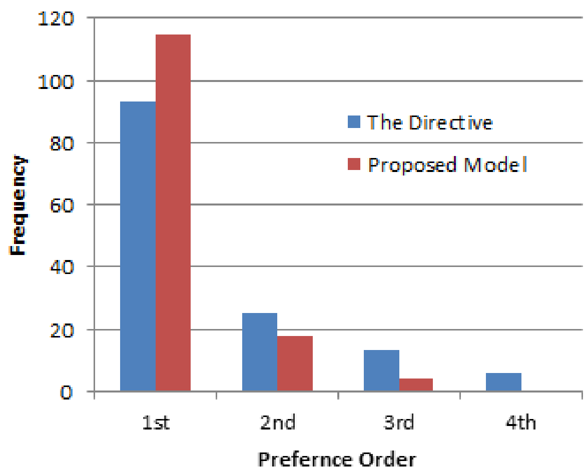

Figure 1. Placement results for 2012 fall semester data.

Table 1. ANOVA of the mean academic scores with the proposed model placement.

Programs:	Count	Mean Score	Variance
Computer Eng.	34	53.52	1819.60
Electronics Eng.	35	51.49	1802.04
Industrial Eng.	35	54.67	1913.35
Aerospace Eng.	33	53.19	1755.36

ANOVA

Source	SS	df	MS	F	$p-$value
Between groups	181.47	3	60.49	0.165	**0.920**
Within Groups	48819.73	133	367.07		
Total	49001.20	136			

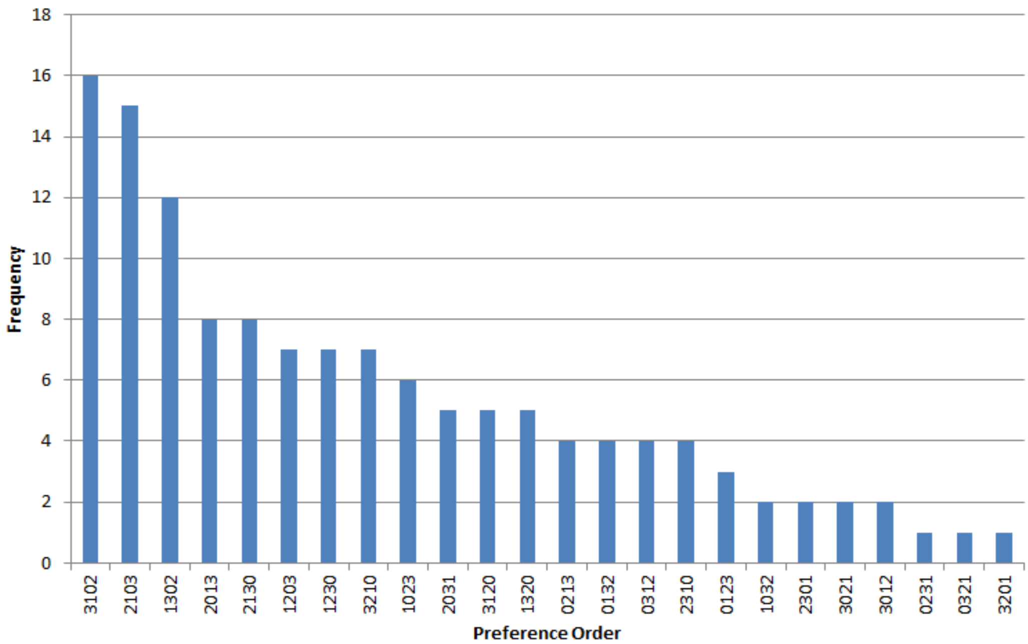

Figure 2. Preference frequency in descending order for 2012 fall semester.

Table 2. Results for the 2012 fall reference distribution (137 cadets).

Data Set	The Directive Disappointment Score	Proposed Method Disappointment Score	Relative Disappointment Efficiency of Proposed
1	110	39	65
2	124	37	70
3	114	37	68
4	129	35	73
5	144	58	60
6	134	45	66
7	146	43	71
8	117	40	66
9	113	36	68
10	131	45	66
Mean	**126.2**	**41.5**	**67**

For uniform and skewed preference distributions, our assignment model produces 66% and 59% less Disappointment accordingly. Proposed model is relatively more efficient in Disappointment metric for both of the distributions. We showed that regardless of the preference distribution proposed assignment model is superior to the algorithm in the directive and also provide a balanced academic score distribution among programs.

5. CONCLUDING REMARKS

In this study we have considered an alternative model for the student-program allocation problem, in which students have preferences over programs and balanced academic score distribution among programs need to be maintained. A practical and easy to apply optimization model is shown significant improvement opportunities without violating system constraints. The proposed model can be extended to solve the assignment problem of graduates of TuAFA who will assign to branches other than pilotage.

Table 3. Results for the uniform preference distributions (250 cadets).

Data Set	The Directive Disappointment Score	Proposed Method Disappointment Score	Relative Disappointment Efficiency of Proposed Method (%)
1	324	99	69
2	318	105	67
3	313	106	66
4	328	109	67
5	331	107	68
6	317	109	66
7	308	105	66
8	318	111	65
9	324	115	65
10	313	108	65
Mean	**319.4**	**107.4**	**66**

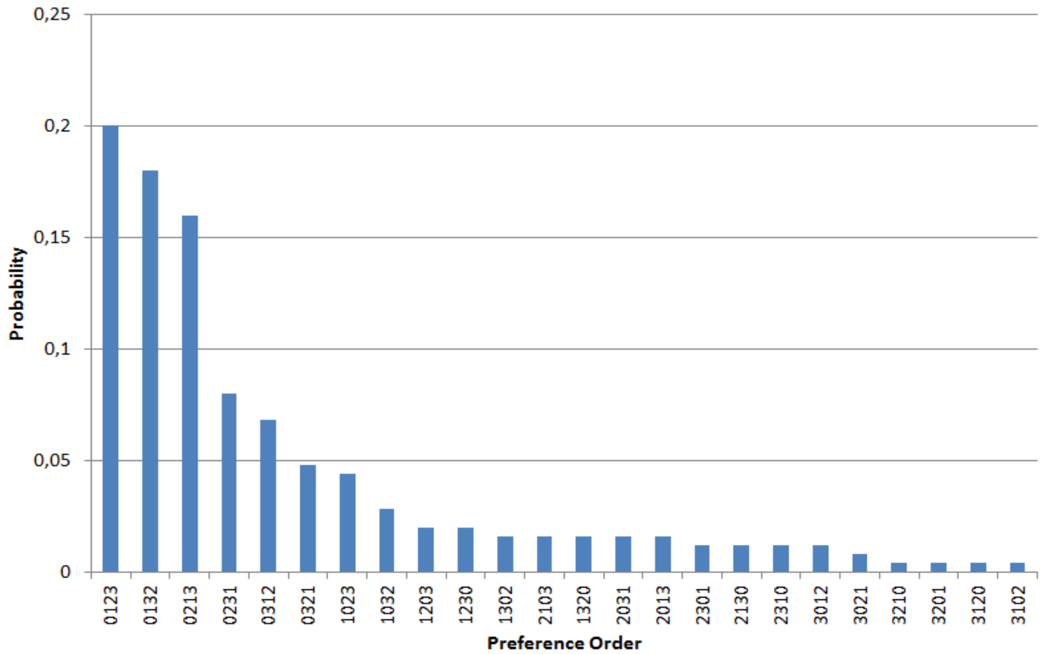

Figure 3. Preference probabilities in descending order for simulated skewed distribution (250 cadets).

Table 4. Results for the skewed preference distribution (250 cadets).

Data Set	The Directive Disappointment Score	Proposed Method Disappointment Score	Relative Disappointment Efficiency of Proposed Method (%)
1	323	155	52%
2	328	172	48%
3	340	182	46%
4	333	172	48%
5	335	166	50%
6	330	171	48%
7	319	166	48%
8	319	160	50%
9	315	153	51%
10	327	160	51%
Mean	**326.9**	**165.7**	**49%**

6. ACKNOWLEDGEMENT

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