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Modelling Choice Selection System of a Public Sector General University in Pakistan

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Abstract: Choice selection in large public sector universities has always remained a critical matter when it comes to distributing the seats against the designated categories of the prospective students. In these universities, thousands of prospective students compete for a limited number of seats allocated for specific undergraduate and postgraduate courses. We design a model for the choice selection system to represent both its structure and behaviour. More specifically, the purpose of this paper is twofold: i) to model the structure of the choice selection system using object modelling technique, and ii) to design a suitable algorithm to generate the merit list. Nowadays, object-oriented languages dominate the programming paradigm; therefore, we use UML class diagram notations to represent the structural model (i.e., class diagram). In this way, the underlying model of the system resembles the real situations that are exploited while the algorithm generates the selection list.

Keywords: Choice Selection System, Admission System, Higher Education System, UML Modelling, Algorithm Design, Software Engineering.

1. INTRODUCTION

In this paper, we have developed the structural model and algorithm to address the choice selection for the public sector general universities. Also, we discuss the factors; i) maximum seat utilization, and ii) how to improve the choice selection system. To the best of our knowledge, the choice selection problem was first studied by Gale and Shapley (Gale. *et al.,* 2009) in their seminal paper in which they proposed a new well- known deferred-acceptance algorithm. Although the existing literature max important contributions from a mechanism design perspective, as in (Aygünyand. *et al.* 2013) and (Bo. 2014) (Abdulkadiroglu. *et al.,* 2003) none of these studies are able to fulfill the requirements of the public sector general universities of Pakistan. In (Fragiadakis. *et al*., 2015) and (Bhatia. *et al.,* 2015) the authors discuss their own specific criteria for distribution of the seats which do not fit in our setting as selections are done under different factors. In these studies, admission algorithms have been designed for special purpose and thus lack the feature of general seat allocation criteria (i.e., district, cut of list, realm of the university, various quota oriented, and waiting list process). The proposed choice selection system will provide a suitable solution, which may enable better seats' utilization for public sector universities in Pakistan.

University admission is a process through which candidates enter into tertiary education. Each university has its own polices and eligibility criteria (i.e., academic background, country, religion, quota, etc.) to select the candidates. Each university has a fixed quota for selecting candidates in different courses. Recently, such efforts include Brazil's racial and income-based seat allocation algorithm and the attempt to increase religious diversity in British schools (Coldron. 2008) In (Aygünyand. *et al.,* 2013), seats are distributed according to racial population and income. In 50% seats are allocated on neighborhood school priority and 50% seats on choice priority. In (Bo. 2014) seats are distributed according to school's criteria and religious status. Many universities aim at distributing seats in different categories and quota for various courses. Due to certain conditions for selection of candidates, appropriate seat allocation has always been an issue. In this study, we select a public sector general university (i.e., University of Sindh- Jasmhoro) in the case study. It is one of the largest universities of Pakistan. This university offers 140 courses in various shifts (i.e., Morning, Evening, and Noon). Each course has its own admission eligibility criteria for accepting candidates. The number of seats distributed in each course according to general merit, district-wise quota, self-finance quota, female quota, and special quota (e.g., sports, disable, and nomination). There are similar constraints in other countries as well. For instance, Boston city schools distribute seats according to district quota In England, city colleges are required to admit group of candidates from the ability range (Dur. *et al.,* 2013). The approaches in literature are based on mathematical formulation but no one adopted object oriented model.

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In this paper, we have developed a suitable structural model and an algorithm to address the choice selection problem in the public sector universities of Pakistan. The structural model is developed using object modelling techniques in UML The advantage of using such a technique is that it simplifies the specification of the complex choice se- lection system. The underlying model of the proposed system is exploited while designing the algorithm that addresses the admission process. While considering the algorithm Cormen. *et al.,* 2001) it does not mean that only predefined notations are used to describe solution but natural language can also be used to express the steps. The algorithm considers the seat distribution according to the specific rules and eligibility criteria of a university.

The organization of the rest of the paper is as follows. In section II, we describe the case study of a large public sector general university in Pakistan. In section III, the underlying model of the choice selection system is given. In section IV and V, we specify the choice selection algorithm with its implementation results. In section VI, we discuss the related work. In section VII, we summarize the work done so for and the future work.

2. CASE STUDY

University of Sindh Jamshoro is a Public Sector University and one of the largest universities of Pakistan. The university's jurisdiction (or realm) includes Hyderabad and Mirpukhas divisions of province Sindh. Also, the university somehow covers Larkana and Sukkur divisions of Sindh. The University has total nine campuses across the province Sindh. Allama I.I Kazi Campus (aka the main campus) is at Jamshoro, Sindh. Currently, there are eight faculties comprising several academic departments and **(Table)**I represent all the faculties and the total number of undergraduate courses they offer at the main campus. The table also shows the total number of seats in each faculty. The University offers both undergraduate and postgraduate courses. In this paper, however, we only consider admissions into undergraduate courses.

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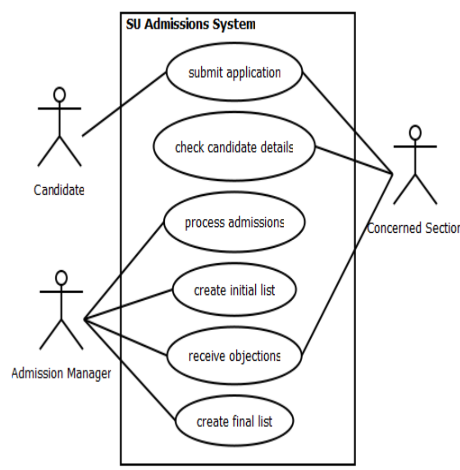
Table I Represents all the faculties and the total number

Faculty	Inst./Dept	Undergrad Courses	Seat Allocation
Arts	**06**	**10**	**1037**
Commerce and Business	**02**	**02**	**377**
Education	**04**	**01**	**111**
Islamic Studies	**03**	**03**	**308**
Law	**01**	**01**	**183**
Natural Sciences	**19**	**25**	**3403**
Pharmacy	**04**	**01**	**111**
Total	**51**	**69**	**6901**

Every year the University announces admissions into these courses to enrol fresh students for the new academic session (i.e., Jan to December). To this purpose, the directorate of admissions at the main campus receives thousands of applications for the admissions against various categories (i.e., Gen-Merit, Female, Employee, Sports, Disabled, Self-Finance, etc.). The University offers various courses in two different shifts (i.e., Morning and Evening). For the morning courses, there were 12708 and 15175 candidates who applied for the academic sessions 2015 and 2016, respectively. The total number of seats for the morning courses are 6901 (Table I) excluding international and other nomination seats.



Fig/ 1. High Level admissions management use cases

Each of the candidates is allowed to mark choices from one to fifteen courses. According to the choice selection rules, these choices of the candidate are ordered in a way that the candidate will be offered one or more courses in higher preference. For instance, a candidate might be offered one course from the first choice on self-finance and the other from the third choice on merit. In this way, the choice selection system is relatively complex.

(Fig. 1) illustrates the high-level activities of the directorate to deal with the admissions for the new academic session. The potential candidates submit their respective applications at the concerned section in the directorate within the due date. The officials receiving the applications check the eligibility of the choices marked. After few days from the closing date, all applications are thoroughly checked before placing them for the admission process. The officials generate the initial merit lists of admissions. These lists are published to receive any objections by the competitor candidates. After resolving the valid objections on the list, the final list (i.e., first merit list) will be published to receive confirmation within specific time period. If there are any candidates who do not confirm their choices in this list, their left-over seats will be assigned to the next candidates who are waiting for their selection. As a result, another list (i.e., second merit list) will be published. Similarly, the final updated (i.e., third merit list) list will be published to mark the end of the admission process for a particular academic session. Such updated merit lists are dispatched to the concerned academic departments so as to start with the new semester for the fresh students.

3. STRUCTURAL MODELING OF CHOICE SELECTION SYSTEM

UML [1, 12] has been considered as a defecto language to model software systems. Object-oriented programming languages (e.g., Java, .Net, PHP, Python, etc.) are being widely used to implement the programme designs. Therefore, we prefer object modeling over the other structured modeling approaches (e.g., data modeling). More specifically, we model the classes of the system under study using UML class diagram notations. Since we intend to transform the object model into Java code, the data types of the class attributes are based on Java programming language.

(Fig. 2) illustrates the classes of the choice selection system of the University. For simplicity, we include the classes that are necessary at this level. However, a detail design can be obtained. In this diagram, classes *Candidate*, *Cand Profile*, and *Student* represent the characteristics of a particular prospective student. The important attributes are *session, gender, testscore*, and composite percentage number (CPN). Attribute CPN is the sum of the candidate's scores in Matriculation, Intermediate, and Entry-Test. The attributes *CPN gender, group, domicile, catagory, choices* which are used by the admissions process.

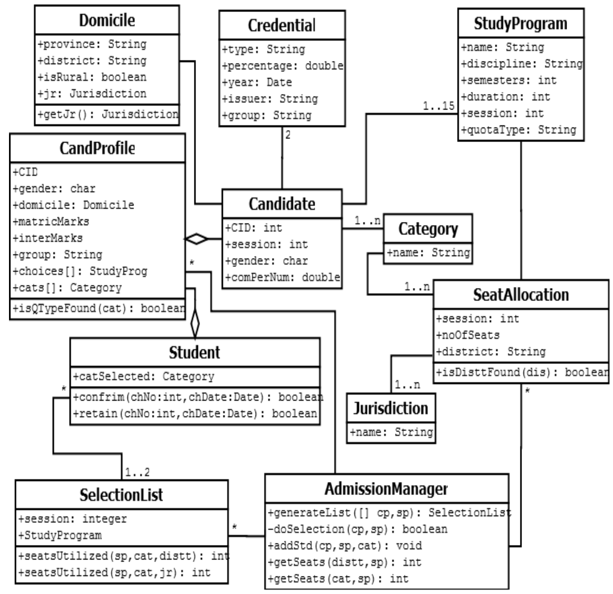


Fig. 2. Meta Model of the choice selection system

Class *Study Program* models undergraduate courses offered by the University. Since each of these courses has a specific number of seats allocated for particular category and jurisdiction, the class *Seat Allocation* represents such information associated with a particular course. For instance, the undergraduate course in English Language has 80 seats for the General Merit category under the University's jurisdiction. Class *Admission Manager* models an artificial entity that is responsible for generating the selection lists. Its operation namely *generateList*, *do Selection*, and *addStd* are defined to process the admissions. Given all candidates data and a particular course, method *generate List* will create the final merit list of a particular course. This method repeatedly calls *doSelection* by passing individual candidate for a particular course. Similarly, in response, the *doSelect* method calls *addStd* method to add the selected candidates into the final merit list against a particular category (e.g., General Merit). For a specific course in a particular academic session, class *Selection List* represents a merit list of the candidates selected against a particular category. In the final merit lists, a student can be offered different courses from his/her choices against one or two different categories. For instance, a candidate might be offered two different courses such as Sindhi Language on General Merit against the second choice and English Language on Self-Finance against the first choice. Therefore, the type of relationship between classes *Selection List* and Student is many to many. The multiplicity constraints on the association between these classes represents such type of relationship.

4. AlLGORTHIM DESIGN AND IMPLEMENTATION

In this section, we describe the algorithm that generates the selection list. Also, we present the results achieved through the proposed choice selection system. Furthermore, we provide the discussion over such results.

As described in section II, the case of the Sindh University choice selection system is a complex system owing to different rules and eligibility criteria for admission in the university.

Algorithm 1 List Generation

```
function GENERATELIST(CandidateProfile[] c, SeatAllocation s )
    for CandidateProfile cp: c do
        List choices = cp.choices
        for StudyProgram sp : choices do
            if SelectionList.getStd(cp.CID,sp) <> null then
                Break
            end if
            if AdmissionManager.doSelection(cp, s, sp) then
                Break
            end if
        end for
    end for
end function
```

Algorithm 1 and Algorithm 2 represent the solution that has been implemented at the university.

Algorithm 1 is the "*List Generation*" algorithm, which generates merit list for every course according to different categories (e.g., general merit, female quota, sports quota etc.). The algorithm accepts *Candidate Profile* and *Seat Allocation* as inputs. *Candidate Profile* is an array of candidate records who have applied for various courses in the university. *Seat Allocation* is a multidimensional array specifying total number of seats available for each course in various categories. The details of these two data structures can be found in section III **(Fig. 2).**

The array of *C andiadte Profile* is sorted on CPN in descending order. For every candidate in *Candidate Profile*, the algorithm checks the candidate's specified choices for admission which again are sorted on preference in descending order. For each choice, the algorithm checks if the candi- date has already been allocated a seat in the said course *(Selection List. getSTD (cp.CID, sp) = null)* because if we are generating second or higher list it will check from previous *Selection List* for not allocating same course in current admission list. If so is the case, the loop breaks, and next candidate is considered for the same procedure. Otherwise, Algorithm 1 calls *do Selection* procedure specified in Algorithm 2 to proceed towards candidate seat allocation.

Algorithm 2 Do Selection

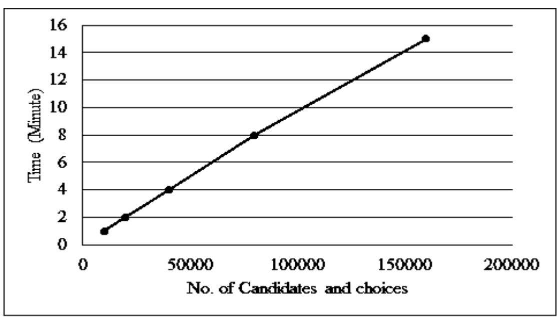
```
function DOSELECTION(CandidateProfile cp, SeatAllocation sa, StudyProgram sp)
    boolean status = false
    String canDist = cp.domicile.district
    String catApplied = "GM"
    String stdCatSelected = SelList.getStd(cp.CID).catSelected.name
    boolean stdCat = cp.isQTypeFound(catApplied)
    if stdCat AND stdCatSelected <> catApplied then
        int seats = sa.getSeats(catApplied, sp)
        if sp.qoutaType == "DISTRICT" then
            if sa.isDisttFound(canDist) then
                int disttSeats = AdmissionManager.getSeats(cp.district, sp)
                int seatsUtilized = SelectionList.seatsUtlized(sp, catApplied, canDist)
                if seatsUtilized < disttSeats then
                    AdmissionManager.addStd(cp, sp, catApplied)
                    status = true
                end if
            end if
        end if
        if sp.qoutaType == "JURISDICTION" then
            if sa.jr.name == cp.domicile.jr.name then
                int jrSeats == sa.getSeats(cp.district.jr.name,sp)
                int seatsUtilized = SelectionList.seatsUtlized(sp, catApplied, cp.district.jr)
                if seatsUtilized < jrSeats then
                    AdmissionManager.addStd(cp, sp, catApplied)
                    status = true
                end if
            end if
        end if
    end if
    return status
```

Algorithm 2 accepts the parameters, *Candidate Profile*, *Seat Allocation*, and *StudyProgram*. Recall from Section II that a student can apply under various categories and under different quotas. We present here pseudo-code for only one category and two quotas for the better understanding of the reader. The algorithm starts off by extracting candidate's district of domicile from his profile and assign it to *canDist. CatApplied* can be used for specifying various categories under which candidate can apply. Here we have taken only one category, i.e., general merit (GM). *StdCat Selected* gets the category under which student has already been selected in the previous list. *StdCat* returns true if the the category under which a candidate has applied is same for which code is checking his eligibility. The algorithm then proceeds by checking the condition that if student has applied for GM and his previous selection is not under the same category *(StdCat AND StdCat Selected <> Cat Applied)* then algorithm proceeds with checking if he can be allocated a seat under the applied category. Otherwise, his eligibility for the next choice is checked.

For allocating a seat, the algorithm first checks the quotas under which program is run and checks candidate's eligibility for each quota. Here, we only explain the procedure for one quota, i.e., District quota. The algorithm first checks if the cur- rent seat allocation has any seats of district as the candidate has domicile for *(sa is DisttFound (canDist)).* If this condition results in false, then student is checked for his eligibility under next category. On the other hand, if this condition results in true, then algorithm checks if the utilized number of districts for which seat allocation is being done is less then the total number of seats for the said district *(if seatsUtilized < disttSeats)*. If so, then the students is a allocated a seat *(Admission Manager.add Std(cp, sp, cat Applied)).* Other- wise, again the student is checked for the next choice. The process continues for each student in the list of *Candidiate Profile*.

5. RESULTS AND DISCUSSION

In this section we measure time and memory of choice selection algorithm and discuss the factors of maximum seat utilization. **(Fig. 3)** is based upon the choice selection algorithm time. It shows that if the number of candidates and choices increase, then the running time increase proportion- ally. For example, if the number of candidates and choices is 50,000, the algorithm take four minutes generating the selection list. Similarly, if the number increases to 100,000 and 150,000, then it takes eight, and twelve minutes respectively. We conjecture from these experiments that the running time of the algorithm is linear.



Fig, 3. Algorithm Time

(Fig, 4) is based upon the choice selection algorithm memory. It shows that running time is directly proportional to number of applying candidates and choices. For the process of generate selection list algorithm occupied 1 mega bite memory in 5000 candidates and choices, 2 mega bite occupy in 10000 candidates and choices.

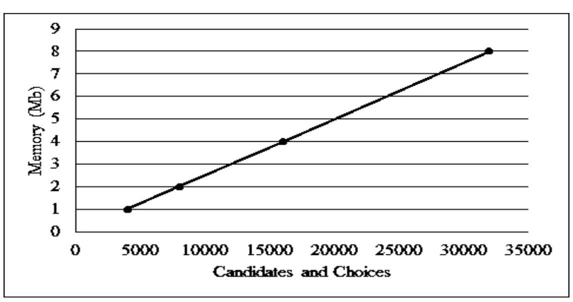


Fig. 4. Algorithm Memory

(Fig. 5) shows total and consumed seats in academic year2015. The data preparation and selection process involves a dataset of 12708 student records from the academic year 2015. Thus, it was observed that 61% seats are consumed in Arts faculty, 93% seats in Commerce and Business, 26% in Edu- cation, 61% in Islamic Studies, 46 % in Law, 80% in Natural Sciences, 99% Pharmacy.

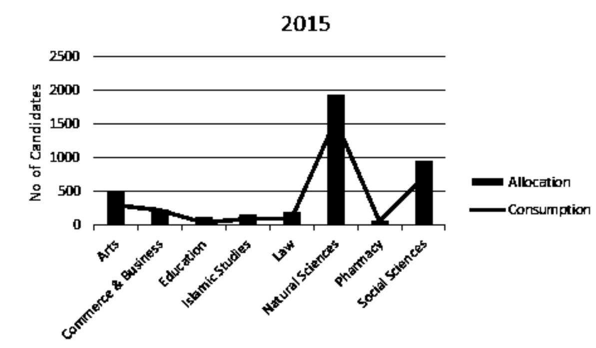


Fig. 5. Total Seats and Allocated Seats

(Fig. 6) shows total and consumed seats in academic year 2016. The data preparation and selection process involves a dataset of 15175 student records from the academic year 2016. Thus, from the experiment it was observed that 60% seats are consumed in Arts faculty, 89% seats in Commerce and Business, 50% in Education, 51% in Islamic Studies, 76 % in Law, 74% in Natural Sciences, 99% Pharmacy.

The results shown in the aforementioned charts suggest that a substantial number of seats remain unutilized every year. The scenario given in next paragraph help to understand the reasons for such unutilized seats.

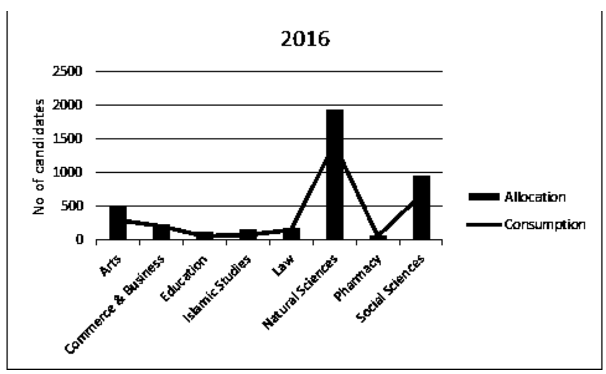


Fig. 6. 2016 Total Seats and Allocated Seats

University of Sindh offered 69 courses in 2015/16. A large number of students applied in market-oriented courses (e.g., CS/IT, Pharmacy, Business, English) which are shown in **(Fig. 7)**. The University allowed each candidate to specify maximum of 10 choices. The results of academic Sessions 2015 and 2016 show that on average students specified maximum of 8 and 9 choices respectively. This suggests, that if we increase maximum number of choices to be specified by the candidates, we will have a probability of getting the good results in seat utilization.

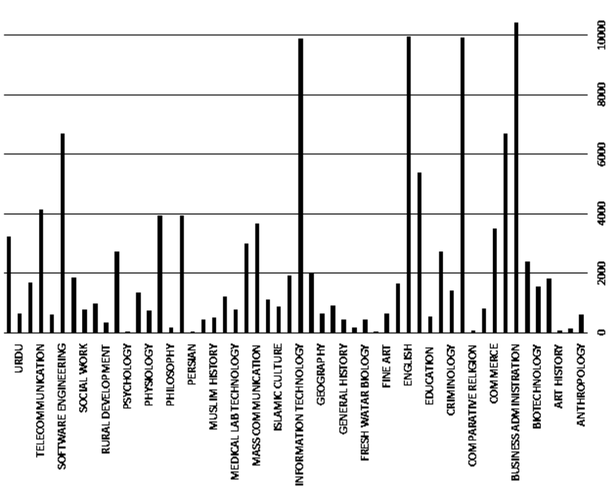


Fig. 7. Candidate Apply for Courses

6. RELATED WORK

(Dur. *et al.,* 2013) discussed a scheme for the seat distribution, where 50% seats are assigned to neighborhood school on priority and remaining 50% are on choice-base priority. A function of reserved seat allocation is developed in (Aygünyand. *et al.,* 2013) where seats are distributed according to racial population and income. Furthermore, an individual candidate can be a part of one or more categories where seats are distributed in more than one category and vacant seats can be filled with candidates having other categories. (Bo. 2014) focuses on a mechanism for allocating seats to candidates in which seats are distributed according to school's criteria and religious status of candidate. (Bhatia *et al.,* 2015) proposes a solution of same type of two problems; i) limited seats and academic score threshold in colleges for applying candidates ii) choice preference, age and some other criteria for the candidates claiming seats in desired colleges. (Abdulkadiroglu. *et al.,* 2003) have used Gale and Shapely algorithm (Gale. *et al.,*2009). They describe the selection of 8th and 9th grade candidates in New York City. Furthermore, they proposed the stable matching mechanism rules of seat distribution and school criteria. Also, seats of colleges were divided into two portions; i) the first half of seats were allocated to top, middle, and lower performers in the previous academics, ii) second half of seats were divided by test score lottery scheme (i.e., those candidates having greater score than 50% of the lottery scheme). Different factors have been preferred in school's criteria for admissions. For instance, some of the schools prefer higher score in previous academics. Similarly, some schools prefer good attendance.

(Fong. *et al.,* 2009) have designed a prototype system called Recommender System for Admission to Universities (RSAU). Such a system provides a solution based on the test scores. In RSAU, candidate's academic background and other factors play a major role in their admissions. Furthermore, they used a hybrid model of neural network, which takes candidate's academic merits, academic background, and the university admission criteria into account. Similarly, in (Adewale. *et al.,* 2007) a neural network model is proposed for the admissions of undergraduates in the universities of Nigeria. They mention a few problems that exist in the current system. For instance, such a system considers other courses for candidate admission if candidate do not meet the criteria for his courses of choice. Prior to their proposed solution, the admission process was not transparent to the candidates.

The study in (Kamada. *et al.,* 2013) focuses on a problem similar tothe admissions into colleges and schools where the doctors have been assigned duties in regions of Japan. In practice, however, this is implemented by simply reducing the individual capacities of the hospitals by some fixed percentage. Many governments are concerned about access to health care in rural communities and trying to implement policies to balance the distribution of doctors in urban and rural areas (Fragiadakis. *et al.,* 2015).

Similarly, a marriage problem in (Roth. 2008) is considered. The marriages held in two groups of couples (i.e., one group of boys and one group of girls) where they were required to select partners of their choice from the designated group. The problem was to match the wishes of boys and girls to marry with a suitable person.

In a study conducted in Kenya by (Wabwoba. *et al.,* 2011) the selection carried out against the candidate's choice where the candidates have chosen the irrelevant subjects. This is because of minimum prerequisites of each course with the prescribed grades in specific subjects. In this model, candidates can regular on the courses at their own choices.

In the previous research, we have analyzed two problem situation regarding selection; i) first, considering higher priority to choice preference and lower to academic score, ii) second, considering inverse of the first. Our problem resembles with later one. Also, we have analyzed that our problem subsumes previous problems discussed in the literature. In addition to this, we used the object modelling approach to structure the system that dominates the programming paradigm. To the best of our knowledge, such an approach has not been used for the said purpose.

7. CONCLUSION

We model a choice selection system for public sector universities in Pakistan. Specifically, we chose the University of Sindh-Jamshoro as a case study in this article, where thousands of applicants seek admissions to various undergraduate and postgraduate courses every year. We describe the case study by considering scenarios of managing admissions for the undergraduate courses against various categories (e.g., General Merit, Self-Finance, etc). The underlying model of the system is represented as a met-model using UML class diagram notations. Such a model is exploited while designing the algorithm that generates the selection list. Also, we discuss the results with respect to seat utilization of the courses offered by the University.

The choice selection at the University ensures the maximum utilization of the seats. However, the proposed choice selection system has a room for the improvement in terms of seats' utilization and usability. Based on the results, we intend to place certain more constraints (e.g., increasing the minimum number of choices for courses) on the system to improve seat utilization. Also, a more interactive model for the users can be considered. Such as adopting an on-line open-house based process to utilize the left-over seats for the prospective students.

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