HIGHER EDUCATION ADMISSION CAPACITY PLANNING USING A LINEARIZED INTEGER GOAL PROGRAMMING MODEL

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Abstract

This paper proposes a linearized integer goal programming model (LIGPM) for solving the general problem of admission capacity planning at the national and/or institutional level and for a given long-term planning horizon. The model aims to satisfy the required key objectives of the Ministry of Education and/or 5-year national plan related to the higher education enrolment problem. The model is described in a general form that can be adopted for any country taking into considerations its special requirements. The national plans for higher education together with relevant data for Saudi Arabia are used as a case study. Many relative objectives of national admission capacity planning have been taken into consideration.

The considered objectives are as follows: Annual growth rate for enrolled students, Percentage of the total number of students enrolled in science and engineering programs, Percentage of total enrolment in higher education regardless of age to the total population in the age group of 18-23 years, Accepted percentage in higher education from high school graduates, Percentage of the total number of students in each discipline of education to the total faculty members, Percentage of the total number of girls to the total number of boys in higher education, Not violating the available resources, Annual growth rate for graduated students and Ratio of graduated students to those enrolled 5 years ago.

Keywords: Higher Education; Admission Capacity Planning; Goal Programming.

1. INTRODUCTION

A growing demand for higher education requires a balanced growth in staff, facilities and infrastructure while the socio-economic relevance lead to the need for a more diversified student specialty for both girls and boys suitable for the market needs. Higher education sector in the Kingdom of Saudi Arabia has observed great leaps during the last National development plan 2011-2015, (Ministry of Economy and Planning, 2015). As in most developed and developing countries, the ministry of Higher Education in the Kingdom of Saudi Arabia is keen on working in compatibility with the government's development plan. To realize this, the ministry designed a number of vital objectives in its new tenth five-year plan and the 25-year plan for higher education, named "AAFAQ", (Ministry of Higher Education, 2015). The higher education authority always tries to solve the question of conflicting aspects concerning objectives, capacity and resources. Goal Programming (GP) is considered as one of the most powerful techniques for many applications comprising conflicting objectives. This paper introduces a Large-Scale Nonlinear Integer Goal Programming model (LSNLIGPM) for admission problem in higher education that can be adapted to the specific needs of a country and/or an institute represented by different needed objectives.

A usual way for solving such dilemma is to work on specific requirements of a separate individual institution for one upcoming year. This paper is more general in terms of the scope and time span. It proposes a general model for solving the problem at a national level and for a long-term planning horizon. The model is flexible to be adjusted to suit different objectives stated by higher authority. The national plans for higher education together with relevant data for Saudi Arabia are used as a case study.

The linear GP model can be solved using many software such as: Microsoft Excel Solver add-ins, (Excel Solver Website, 2015), (Linear Program Solver LiPS, 2016), (Tora software website, 2015), (QM for Windows software website, 2015) and (LINGO, 2009).

2. LITERATURE REVIEW

Enrolment management has been defined as any institutional attempt to influence the number, mix, and quality of students through recruitment and retention strategies, (Wilkinson, 2007) and (University of the Fraser Valley Strategic Enrolment Management "SEM", 2014). Many attempts have been made to mathematically model a variety of problems in admission capacity planning that were applied to different problems, (Mansmann and Scholl, 2007) and (Dahlan, and Yahaya, 2010).

A considerable number of research studies have been proposed to solve the problem by using GP technique alone or combined with another classical mathematical methods or intelligent optimization algorithms. The main reason of using GP is its capability of simultaneously satisfy several conflicting goals relevant to the decision-maker. GP is an extension of linear programming involving multiple goals, (Tovar and Piedra, 2012).

Applications of GP were used in modeling university planning appearing in early 1970s by (Lee and Clayton, 1972). The scope of this study was limited to the planning of one college within the university. Additionally, the planning horizon was also limited to one year. (Lee and Moore, 1974) formulated a GP model suitable for United States institution's administrative policies. Also, (Schroeder, 1974) introduced a new approach for recourse planning in the universities based on GP. Data were gathered at the University of Minnesota, Minnesota State, United States of America. In 1981, (Kendall and Luebbe 1981) developed a GP model to manage recruitment activities in the small four-year Concordia College in Nebraska. They concentrated on university financial related problems for private colleges. Their model identifies the type and number of activities that must be completed each quarter in order to reach an enrollment goal for a given year. Again, in 1981, a goal programming-based DSS has been presented by (Franz et al., 1981). They reported that testing of their DSS on four academic decision makers in a large US Midwestern University shows considerable promise for supporting decision makers. (Soyibo and Lee 1986) developed a large scale GP model for an efficient resource allocation for Ibadan University, Nigeria which includes eight faculties and a college of medicine. A DSS for student admission policy to Kuwait University has been developed (Elimam, 1991) to find the optimal admission policy.

(Gottlieb, 2001) had discussed admissions offices at selective colleges. The aim was to balance a number of conflicting issues in deciding which applicants to admit using an integer programming model. (Vinnik and scholl, 2005) proposed a university's capacity planning; it aimed at optimizing the academic decision making and admission capacity planning by simulation and evaluation of strategic plans. Khan (2009) used a product mix model of linear programming for university's optimal enrollment management.

Sugrue (2010) described the application of linear programming as a decision tool in merit based financial aid decisions at a medium size private university. Mashat et al. (2012) proposed a decision support system based on an absorbing Markov model for helping decision makers at King Abdulaziz University, Saudi Arabia in controlling student's flow transition enrollment. Kassa (2013) used a linear programming approach for placement of applicants to study programs at the College of Business and Economics, Bahir Dar University in Ethiopia. A multi-aggregator models for fuzzy queries and ranking for admission students in a university based on an evolutionary computing approach has been introduced (Alsharafat, 2013). Recently, Ragab et al. (2014) proposed a classification algorithm for students' college enrollment approval using data mining. Ragab et al. (2014) presented also a new college admission system using hybrid recommender based on data mining techniques and knowledge discovery rules.

In a paper written by (El-Quliti et al., 2015), a Nonlinear Integer Goal Programming Model for solving the problem of admission capacity planning in education institutions is proposed. The model is used to solve the problem at King Abdulaziz University, Saudi Arabia to achieve the key objectives stated by higher authorities for one upcoming year only. In another paper written by (El-Qulity and Mohamed, 2015) the authors proposed another nonlinear integer goal programming model (NIGPM) for solving the general problem of admission capacity planning in a country level as a whole. The data for Saudi Arabia is used as a case study and a novel evolutionary algorithm based on modified differential evolution (DE) algorithm is used to solve the complexity of the NIGPM for the upcoming year only.

Based on the above literature review, it can be concluded that most of these studies are limited in the used institutional scope and planning time horizon of one year only. It can be also concluded that the admission capacity planning for higher education in universities is still an open area for researches; many further studies must be carried out in different aspects to develop appropriate optimization methodologies using different mathematical methods coupled with soft computing techniques as proposed in this research to overcome the previous two limitations.

3. PROBLEM FRAMEWORK

The problem of planning a National Admission Capacity strategy in HE is a common dilemma everywhere. Usually any country performs National plans concerning the HE for along a time horizon of 3-5 years. These plans usually include a number of objectives to be fulfilled thought the planning period. In general, these objectives can be included some or all of the following points:

- Annual growth rate for enrolled students.
- Percentage of the total number of students enrolled in science and engineering programs.
- Percentage of total enrolment in higher education regardless of age, to the total population in the age group of 18-23 years.
- Accepted percentage in higher education from high school graduates.
- Percentage of the total number of students in each discipline of education to the total faculty members.
- Percentage of the total number of girls to the total number of boys in higher education.
- Not violating the available resources.
- Annual growth rate for graduated students.
- Ratio of graduated students to those enrolled 5 years ago.

These objectives are somehow conflicting; the satisfaction of one part will be at the expense of other. One way to solve this problem is to formulate a goal programming model; the model will constitute goals representing these objectives and tries to minimize the deviations from these goals.

The algorithm starts with studying the strategic plans related to HE and extract the required objectives for the admission problem. The decision maker will express different objectives to be achieved in the upcoming years of the planning horizon. These desired objectives may include among other: the annual growth rate for enrolled students, percentage of the total number of students enrolled in different education specialties, percentage of total enrollment in higher education to the total population in the age of higher education (18-23 years), accepted percentage in higher education from high school graduates, student to faculty ratios, percentage of the number of girls to the number of boys, the available resources constraints, annual growth rate for graduated students, ratio of graduated students to those enrolled 5 years ago, and other similar objectives related to the country under consideration. The stated objectives together with relevant data and parameters are used to formulate a goal programming model revealing the stated problem. The obtained results will be used as recommendations for the decision maker to solve the complex planning problem for the required time horizon.

4. GOAL PROGRAMMING MODEL

As a case study, the mathematical model will cover the main objectives stated in the current Kingdom of Saudi Arabia (KSA) Development Plan and that stated in KSA Higher Education Strategic Plan (AAFAQ) for the next 25 Years. It will be restricted to a-3 year planning horizon as an example for application, but it can be extended to longer time span with little modifications.

4.1 Decision Variables

To design the decision variables for the problem, it is necessary to represent all the different problem attributes. Let the decision variables be denoted by:

$x_{i,j,k}^{y,u} = x_{\text{status, gender, program}}^{\text{year of the plan,university}}$ = No of students, where different attributes are shown in Table 1:

Table1. Problem attributes and their values.

Attributes	Values
y = Year of the plan	y = 1 for the first year of the next plan 2016, 2 for the second and 3 for the last year, y = 0 for the last year in the previous plan (current year, 2015), y= -1 for year 2014 and so on.
u = University	u = a university, u ∈ U, the set of all universities in the country.
i = Status	E for Enrolled and G for Graduated
j = Gender	b for boys section and g for girls section
k = Education Program	m = a college in the medicine specialty, m ∈ M, the set of all colleges in the Medicine specialty, s = a college in the Science & Engineering specialty, s ∈ S, the set of all colleges in the Science and Engineering specialty, a = a college in the arts specialty, a ∈ A the set of all colleges in the Arts specialty and T for the total number in all specialties M, S and A in all universities U.

4.2 The Problem Goals

i. Increase in the Enrollment Rate:

It is required to increase the enrolment of students (boys and girls) in higher education with an average annual growth rate of p_r^y.

$\sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y,u} - \sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y-1,u} + d_y^- \geq p_r^y.(\sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y-1,u})$ y = 1, 2, 3. (1-3)

$\sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y,u} - \sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y-1,u} + d_{y+3}^- \geq p_r^y. \sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y-1,u}$, y = 1, 2, 3. (4-6)

ii. Control the Education Tracks:

The percentage of the total number of students enrolled in science and engineering and medical programs to the total number of students enrolled in higher education ≥ p_s^y:

$\sum_{u\in U}\sum_{k=m,s} x_{E,b,k}^{y,u} + d_{y+6}^- \geq p_s^y. \sum_{u\in U}\sum_{j\in J} x_{E,b,j}^{y-1,u}$, y = 1, 2, 3. (7-9)

$\sum_{u\in U}\sum_{k=m,s} x_{E,g,k}^{y,u} + d_{y+9}^- \geq p_s^y. \sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y-1,u}$, y = 1, 2, 3. (10-12)

The percentage of the total number of students enrolled in medical programs to the total number of students enrolled in science and engineering ≥ p_m^y :

$\sum_{u\in U}\sum_{k=m\in M} x_{E,b,k}^{y,u} + d_{y+12}^- \geq p_m^y. \sum_{u\in U}\sum_{k=s\in S} x_{E,b,j}^{y-1,u}$, y = 1, 2, 3. (13-15)

$\sum_{u\in U}\sum_{k=m\in M} x^{y,u}_{E,g,k} + d^{-}_{y+15} \geq p^{y}_{m}.\sum_{u\in U}\sum_{k=s\in S} x^{y-1,u}_{E,g,k}$, y = 1, 2, 3. (16-18)

iii. Percentage of Enrolment to Population and to High School Graduates:

The percentage of total enrolment in higher education regardless of age, to the total population in the age group of 18-23 years ≥ p^{y}_{p}, and the accepted percentage in higher education from high school graduates in the same year ≥ p^{y}_{h}.

$\sum_{u\in U}\sum_{j\in J}\sum_{k\in K} x^{y,u}_{E,j,k} + d^{y-}_{y+18} \geq \max\left[\left(\frac{1}{5}.p^{y}_{p}.\ N^{y-1}_{C}\right),\left(p^{y}_{h}.\ N^{y-1}_{H}\right)\right]$, y = 1, 2, 3 (19-21)

Where:

p^{y}_{p}=The percentage of total enrolment in higher education regardless of age, to the total population in the age group of 18-23years in year y.

N^{y}_{C}= Population of Saudi Arabia in the age of 18-23 years in year y.

p^{y}_{h}= The accepted percentage in higher education from high school graduates in year y.

N^{y}_{H}= High school graduates in a year y will be decreased by the number of boys for bachelor Scholarships abroad (N^{y-1}_{b}) and the number of girls for bachelor Scholarships abroad (N^{y-1}_{g}).

iv. Student-to-Faculty Ratio:

The percentages of the total number of students in each discipline of university education to the total faculty (F) in that specialty are as follows:

Medicine ($m \in M$) ≤ β^{y}_{M},

Engineering &Science ($e \in E$) ≤ β^{y}_{E},

Arts ($a \in A$) ≤ β^{y}_{A},

Total University ($u \in U$) ≤ β^{y}_{U}.

$\sum_{u\in U}\sum_{m\in M} x^{y,u}_{E,b,m} - d^{+}_{y+21} \leq \frac{1}{t_M}.\beta^{y}_{M}.F^{y,U}_{b,M}$, y = 1, 2, 3. (22-24)

$\sum_{u\in U}\sum_{m\in M} x^{y,u}_{E,g,m} - d^{+}_{y+24} \leq \frac{1}{t_M}.\beta^{y}_{M}.F^{y,U}_{g,M}$, y = 1, 2, 3. (25-27)

$\sum_{u\in U}\sum_{s\in S} x^{y,u}_{E,b,s} - d^{+}_{y+27} \leq \frac{1}{t_S}.\beta^{y}_{S}.F^{y,U}_{b,S}$, y = 1, 2, 3. (28-30)

$\sum_{u\in U}\sum_{s\in S} x^{y,u}_{E,g,s} - d^{+}_{y+30} \leq \frac{1}{t_S}.\beta^{y}_{S}.F^{y,U}_{g,M}$, y = 1, 2, 3. (31-33)

$\sum_{u\in U}\sum_{a\in A} x^{y,u}_{E,b,a} - d^{+}_{y+33} \leq \frac{1}{t_A}.\beta^{y}_{A}.F^{y,U}_{b,A}$, y = 1, 2, 3. (34-36)

$\sum_{u\in U}\sum_{a\in A} x^{y,u}_{E,g,a} - d^{+}_{36} \leq \frac{1}{t_A}.\beta^{y}_{A}.F^{y,U}_{g,A}$, y = 1, 2, 3. (37-39)

$\sum_{u\in U}\sum_{k\in K} x^{y,u}_{E,b,k} - d^{+}_{y+39} \leq \frac{1}{t_M}.\beta^{y}_{U}.F^{y,U}_{b,T}$, y = 1, 2, 3. (40-42)

$\sum_{u\in U}\sum_{k\in K} x^{y,u}_{E,g,k} - d^{+}_{y+42} \leq \frac{1}{t_M}.\beta^{y}_{U}.F^{y,U}_{g,T}$, y = 1, 2, 3. (43-45)

Where;

$F^{y,U}_{j,K}$ = Number of faculty members for gender j in specialty K in all Universities U, $j = b, g$ and $K = M, S, A$ and U, t_k = Number of years in a program k.

v. Enrolled Girls-to-Boys Ratio:

The percentage of the number of enrolled girls to the total number of enrolled boys in higher education ≥ p^{y}_{g}:

$\sum_{u\in U}\sum_{k\in K} x^{y,u}_{E,g,k} + d^{-}_{y+45} \geq p^{y}_{g}.\sum_{u\in U}\sum_{k\in K} x^{y,u}_{E,b,k}$, y = 1, 2, 3. (46-48)

vi. Resources Constraints for Enrolment:

All the resources of the teaching process are collected in the total budget required for a University u that should not exceed a certain total limit of B_u^y at any year y of the planning horizon.

Let:

c_u^y = cost per student in a University u in a year y, and

B_u^y= Maximum budget for a university u in a year y,

Then:

$\sum_{u\in U}\sum_{j\in J}\sum_{k\in K} x_{E,j,k}^{y,u} - d_{y+48}^{+} \le \sum_{u\in U} B_u^y / c_u^y$, y = 1, 2, 3. (49-51)

vii. Increase in the Number of Graduated Students:

The Plan projects that over the same period, the number of graduates will increase with an average annual rate = q_r^y.

viii. Increase in the Graduation Rate:

Percentage of students who have completed their studies in a given year to the total number of students enrolled in universities five years before that year=q_d^y .

These two goals will be expressed as follows:

$\sum_{u\in U}\sum_{m\in M} x_{G,b,m}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{m\in M} x_{G,b,m}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{m\in M} x_{E,b,m}^{y-5,u}\right]$, y = 1, 2, 3. (52-54)

$\sum_{u\in U}\sum_{s\in S} x_{G,b,s}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{s\in S} x_{G,b,s}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{s\in S} x_{E,b,s}^{y-5,u}\right]$, y = 1, 2, 3. (55-57)

$\sum_{u\in U}\sum_{a\in A} x_{G,b,a}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{a\in A} x_{G,b,a}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{a\in A} x_{E,b,a}^{y-5,u}\right]$, y = 1, 2, 3. (58-60)

$\sum_{u\in U}\sum_{m\in M} x_{G,g,m}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{m\in M} x_{G,g,m}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{m\in M} x_{E,g,m}^{y-5,u}\right]$, y = 1, 2, 3. (61-63)

$\sum_{u\in U}\sum_{s\in S} x_{G,g,s}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{s\in S} x_{G,g,s}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{s\in S} x_{E,g,s}^{y-5,u}\right]$, y = 1, 2, 3. (64-66)

$\sum_{u\in U}\sum_{a\in A} x_{G,g,a}^{y,u} \ge \max\left[\left(1+q_r^y\right).\sum_{u\in U}\sum_{a\in A} x_{G,g,a}^{y-1,u}, q_d^y . \sum_{u\in U}\sum_{a\in A} x_{E,g,a}^{y-5,u}\right]$, y = 1, 2, 3. (67-69)

4.3 The Objective Function

Once all goals and constraints are identified, management should analyze each goal to see if underachievement or overachievement of that goal is an acceptable situation:

- If overachievement or underachievement is allowed, the corresponding deviation variable can be eliminated from the objective function.
- If a goal should be attained exactly, both deviation variables must be included in the objective function.

Those deviation variables that are needed to be minimized should be included in the objective function.

Let:

d_n^-= Underachievement of the n^{th} target,

d_n^+= Overachievement of the n^{th} target.

Where: n is the number of the constraint,

Consider the case when higher authority decides that all goals will have the same priority and weight; then the corresponding objective function is formulated as follows:

Minimize z = $\sum_{i=1}^{n-} d_i^- + \sum_{i=1}^{n+} d_i^+$ (70)

Where: n^- = the number of underachievement deviation variables,

n^+= the number of overachievement deviation variables.

5. ADMISSION CAPACITY PLANNING FOR SAUDI ARABIA AS A CASE STUDY

Saudi Arabia as most of the countries faces a number of challenges related to admission capacity planning for HE as those stated in section 3 and mathematically formulated in section 4. It can be noticed that the proposed mathematical model contains two separate parts with respect to the decision variables; enrolment

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part and graduation part. So, both parts will be treated individually; the proposed LSNIGPM will be used to represent the enrolment part presented in equations (1- 57) with its objective function that minimize the sum of all the considered deviation variables, while inequality relations (58 – 69) will be used to solve directly the graduation part.

Relevant parameters and data for the model related to Saudi Arabia are collected and presented in Table 2, Central Department of Statistics and Information (2015). Table 3 represents the input data in the current year 2015, and Table 4 represents the input data for years needed in the mathematical model.

6. PROBLEM SOLUTION, RESULTS AND DISCUSSIONS

The optimal solution is found using “LiPS” software (2016) in terms of minimizing the objective function value and the optimal design decision variables is given in Table 5.

7. CONCLUSIONS AND POINTS FOR FUTURE RESEARCHES

A general problem of admission capacity planning in HE is formulated including most common objectives stated in common National development plans. A framework of the problem with its solution methodology over a specified time horizon is presented, and a LIGPM is proposed to formulate the problem with relevant goals, decision variables, constraints and objective function.

The considered goals include the annual growth rate for enrolled students, the percentage of the total number of students enrolled in different programs, the percentage of total enrollment to the population in the age group of the university and to the graduates from high school, student to faculty ratio, girls to boys ratio, annual growth rate for graduated students and the ratio of graduates to those enrolled 5 years ago and the available resources constraints.

Table 2. Input parameters related to the Kingdom of Saudi Arabia.

Symbol	Meaning	Value
p_r^y	Annual growth rate for enrolled students in year y of the planned horizon.	4.5%
p_s^y	Percentage of the total number of students enrolled in science & engineering and medical programs to the total number of students enrolled in higher education in year y of the planned horizon.	60%
p_m^y	Percentage of the total number of students enrolled in medical programs to the total number of students enrolled in science & engineering and in year y of the planned horizon.	16.5%
p_p^y	Percentage of total enrolment in higher education regardless of age, to the total population in the age group of 18-23years in the same year y of the planned horizon.	50%
p_h^y	Accepted percentage in higher education from high school graduates in year y of the planned horizon.	55%
p_g^y	Percentage of the total number of enrolled girls to the total number of boys enrolled in year y of the planned horizon.	90%
Percentage of the total number of students in each discipline of university education to the total faculty (F) in that specialty in year y of the planned horizon is:		
β_M^y	Medicine	10 :1
β_S^y	Science & Engineering	17: 1
β_A^y	Arts	22:1
β_U^y	Total University	20: 1
q_r^y	Annual growth rate of the number of graduates for year y of the planning horizon.	7.2%.
q_d^y	The planned percentage of students who will complete their studies in year y of the planned horizon to the total number of students enrolled five years ago.	85%

Table 3. Input data related to the Kingdom of Saudi Arabia in the current year 2015.

Symbol	Meaning	**Value**
$x_{E,b,T}^{y-1,U}$	Total number of boys enrolled in Saudi Arabia in all universities in year y-1 (2015 = last year of the previous National plan).	214,603
$x_{E,g,T}^{y-1,U}$	Total number of girls enrolled in Saudi Arabia in all universities in year y-1 (2015 =last year of the previous National plan)	199,185
$x_{G,b,M}^{y-1,U}$	Number of graduated boys in the Kingdom in year 2015 (medicine)	3,191
$x_{G,b,S}^{y-1,U}$	Number of graduated boys in the Kingdom in year 2015 (science & engineering specialty)	18,103
$x_{G,b,A}^{y-1,U}$	Number of graduated boys in the Kingdom in year 2015 (arts specialty)	13,851
$x_{G,g,M}^{y-1,U}$	Number of graduated girls in the Kingdom in year 2015 (medicine)	3,456
$x_{G,g,S}^{y-1,U}$	Number of graduated girls in the Kingdom in year 2015 (science & engineering specialty)	22,871
$x_{G,g,A}^{y-1,U}$	Number of graduated girls in the Kingdom in year 2015 (arts)	34,797

The proposed LIGPM is developed in general form so that it can be adapted easily for realizing general objectives stated for a given education plan. A detailed 3-years National plan for HE in Saudi Arabia with relevant parameters and data is demonstrated.

As future researches, it is proposed to consider the following points:

- To apply the proposed model to satisfy the specific objectives stated by individual HE institution for a given planning horizon.
- To apply a similar model for any other cases considering stated objectives in their higher education enrollment plans.
- To apply the proposed model to satisfy the objectives of a National enrollment plan for a time horizon of five or longer year spans using a suitable programming language.
- To consider different priorities and weights for various goals stated in the proposed mathematical model.
- To design a friendly user decision support system with flexible input and output interfaces familiar to the technical abbreviations of decision makers in the field.

Table 4. Input data related to the Kingdom of Saudi Arabia for different years.

Symb.	**Meaning**	**Value in Year y**		
		2015	**2016**	**2017**
N_C^y	Population of Saudi Arabia in the age of 18-23 years.	1,297,000	1,335,910	1,375,987
N_H^y	Total number of High school graduates.	404,742	422955	441988
N_b^y	Number of boys for bachelor Scholarships abroad.	22,644	24,908	27,399
N_g^y	Number of girls for bachelor Scholarships abroad.	8,477	9,325	10,257
B_u^y	Total Budget for a university u in a year y (in million SAR).	32,500	35,750	39,325
c_u^y	Average cost of one student in a university u in a year y (in SAR).	56,250	61,875	68,063
$F_{bM}^{y,U}$	Number of faculty in all universities (boys section, medical specialty)	7,425	8,168	8,984
$F_{g,M}^{y,U}$	Number of faculty in all universities (girls section, medical specialty)	4,433	4,876	5,364
$F_{b,S}^{y,U}$	Number of faculty in all universities (boys	19,346	21,281	23,409

	section, science and engineering)			
$F_{g,S}^{y,U}$	Number of faculty in all universities (girls section, science and engineering)	8,658	9,524	10,476
$F_{b,A}^{y,U}$	Number of faculty in all universities (boys section, arts specialty)	9,431	10,374	11,412
$F_{g,A}^{1,U}$	Current number of faculty in all universities (girls section, arts specialty)	9,776	10754	11829
$F_{b,T}^{y,U}$	Number of faculty in all universities (boys section, all specialties)	37,245	40,970	45,066
$F_{g,T}^{y,U}$	Number of faculty in all universities (girls section, all specialties)	23,405	25,746	28,320
		Value in Year y		
		2011	**2012**	**2013**
$x_{E,b,M}^{y-5,U}$	Number of enrolled boys (medicine).	8,518	9,370	10,307
$x_{E,b,S}^{y-5,U}$	Number of enrolled boys in year y-5, y-4 and y-3. (science & engineering specialty)	93,807	103,188	113,506
$x_{E,b,A}^{y-5,U}$	Number of enrolled boys (arts specialty)	34,301	37,731	41,504
$x_{E,g,M}^{y-5,U}$	Number of enrolled girls (medicine)	7,114	7,825	8,608
$x_{E,g,S}^{y-5,U}$	Number of enrolled girls (science & engineering)	92,867	102,154	112,369
$x_{E,g,A}^{y-5,U}$	Number of enrolled girls (arts)	38,993	42,892	47,182

Table 5. Optimal values of design variables for the case study.

Decision Variable	**Meaning**	**Optimal Solution**		
		Planning Year y		
		2016	**2017**	**2018**
$x_{E,b,M}^{y,U}$	Number of enrolled boys in medical specialty	12,250	13,451	13,907
$x_{E,b,S}^{y,U}$	Number of enrolled boys in science specialty	54,856	56,612	69,936
$x_{E,g,M}^{y,U}$	Number of enrolled girls in medical specialty	9,325	10,244	11,465
$x_{E,g,S}^{y,U}$	Number of enrolled girls in science specialty	46,729	52,044	53,003
$x_{E,bA}^{y,U}$	Number of enrolled boys in arts specialty	34,907	41,629	43,566
$x_{E,g,A}^{y,,U}$	Number of enrolled girls in arts specialty	39,666	40,901	43,632
$x_{G,bM}^{y,U}$	Number of graduated boys in medical specialty	7,240	7,965	8,467
$x_{G,b,S}^{y,,U}$	Number of graduated boys in science specialty	47,736	49,710	51,639
$x_{G,b,A}^{y,U}$	Number of graduated boys in arts specialty	29,156	32,071	34,328
$x_{G,g,M}^{y,U}$	Number of graduated girls in medical specialty	6,047	6,651	6,954
$x_{G,g,S}^{y,U}$	Number of graduated girls in science specialty	36,937	38,831	40,638
$x_{GgA}^{y,U}$	Number of graduated girls in arts specialty	33,144	36,458	39,843
z = sum of nonzero deviation variables		273,767		

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REFERENCE LIST

Alsharafat, W. S. (2013). Steady state genetic algorithm in university admission decision, Contemporary Engineering Sciences, vol. 6, no. 5, pp. 245–254.

Central Department of Statistics and Information (2015). Saudi Arabia, Statistical Year Book.

Dahlan, S.F.M. and Yahaya, N. A. (2010). "A system dynamics model for determining educational capacity of higher education institutions,"in Proceedings of the 2nd International Conference on Computational Intelligence, Modeling and Simulation (CIMSim'10), pp. 285–290, September 2010.

Eliman, A. A. (1991). A decision support system for University admission policies," European Journal of Operational Research, vol. 50, no. 2, pp. 140–156.

El-Qulity, S.A. and Mohamed A. W., (2015). A Generalized National Planning Approach for Admission Capacity in Higher Education: a nonlinear Integer Goal Programming Model with a Novel Differential Evolution Algorithm, Computational Intelligence and Neuroscience, Hindawi Publishing Corporation, Article ID 809271.

El-Quliti, S. Ragab, A.H., Abdelaal, R. Mohamed, A. Mashat, A. Noaman, A. and Altalhi,A. (2015). A Nonlinear Goal Programming Model for University Admission Capacity Planning with Modified Differential Evolution Algorithm, Mathematical Problem in Engineering, Vol. 2015, ID 892937, Article ID 892937, doi.org/10.1155/2015/892937.

Excel Solver Website (2015), [Online]. Available at: http://www.excel-easy.com/data-analysis/solver.html. Accessed in 16 March 2015.

Franz, L. S., Lee, W.M. and VanHorn, J. C. (1981). An adaptive decision support system for academic resource planning, Decision Sciences, vol. 12, no. 2, pp. 276–293, 1981.

Gottlieb, E. (2001). Using integer programming to guide college admissions decisions: a preliminary report, consortium for computing in small colleges," Journal of Computing Sciences in Colleges, vol. 17, no. 2, pp. 271–279.

Kassa, B. A. (2013). A linear programming approach for placement of applicants to academic programs," Springer Plus, vol. 2, no. 1, pp.1–7.

Kendall, K. E. and Luebbe, R. L. (1981). Management of college student recruiting activities using goal programming, Decision Sciences, vol. 12, no. 2, pp. 193–205, 1981.

Khan, H. (2009). A product mix model of linear programming for University's optimal enrollment management," in Proceedings of the Conference for Industry and Education Collaboration, American Society for Engineering Education, Orlando, Fla,USA.

Lee, S. M. and Clayton, E. R. (1972). A goal programming model for academic resource allocation, Management Science, vol. 18, no.8, pp. B-395–B-408, 1972.

Lee S. M. and Moore, L. J. (1974). Optimizing university admissions planning, Decision Sciences, vol. 5, no. 3, pp. 405–414.

LINGO (2009), Lingo Optimization Modeling Software for Linear, Nonlinear, and Integer Programming, LINGO, 2009, http://www.lindo.com/.

Linear Program Solver software "LiPS" (2016), [Online]. Available at: http://linear-program-solver.soft112.com/. Accessed in 11 February 2016.

Mansmann, S. and Scholl, M. H. (2007). "Decision support system for managing educational capacity utilization," IEEE Transactions on Education, vol. 50, no. 2, pp. 143–150.

Mashat, A.S., Ragab, A.M. and Khedra, A.M. (2012). Decision support system based Markov model for performance evaluation of students flow in FCIT-KAU," in Proceedings of the ICCIT, pp.409–414.

Ministry of Economy and Planning (2015), Ninth National Development Plan, Kingdom of Saudi Arabia, [Online]. Available: http://www.mep.gov.sa/, accessed in16 January 2015.

Ministry of Higher Education (2015), The future plan for university education in the Kingdom of Saudi Arabia (AAFAQ), Saudi Arabia, website: http://aafaq.mohe.gov.sa, accessed in 15 February 2015.

QM for Windows software website (2015), [Online] Available at:

http://qm-for-windows.software.informer.com/download/ Accessed in 22 April 2015.

Ragab, A. M. Mashat, A. S. and Khedra, A. M. (2014). Design and implementation of a hybrid recommender system for predicting college admission, International Journal of Computer Information Systems and Industrial Management Applications, vol. 6, pp. 35–44.

Ragab, A. M., Noaman, A. Y., Al-Ghamdi, A. S. and Madbouly, A. I. (2014). A comparative analysis of classification algorithms for students college enrollment approval using data mining," in Proceedings of the Workshop on Interaction Design in Educational Environments (IDEE '14), pp. 106–113, Albacete, Spain, June 2014.

Schroeder, R. G. (1974). Resource planning in university management by goal programming," Operations Research, vol. 22, no. 4, pp.700–710, 1974.

Soyibo, A. and Lee, S.M. (1986). "A multi-objective planning model for university resource allocation," European Journal of Operational Research, vol. 27, no. 2, pp. 168–178.

Sugrue, P. K. (2010). An optimization model for the allocation of university based merit aid," Journal of Student Financial Aid, vol.40, no. 2, pp. 21–30.

Tora software website (2015), [Online] Available at: http://tora.software.informer.com/2.1/ Accessed in 12 April 2015.

Tovar, E. and Piedra, N. (2014). Guest editorial: open educational resources in engineering education: various perspectives opening the education of engineers, IEEE Transactions on Education, vol. 57, no. 4, pp. 213–219, 2014.

University of the Fraser Valley Strategic Enrolment Management (SEM) (2014). Plan 2014–2019, http://www.ufv.ca/media/assets/senate/SEM-2014-Plan-FINAL-Approved-by-the-Board-Sept-4,-2014.pdf.

Vinnik, S. and Scholl, M. H. (2005). UNICAP: efficient decision support for academic resource and capacity management," in Proceedings of the TED Conference on e-Government (TCGOV '05), Bolzano, Italy.

Wilkinson, R. B. (2007). Strategic Enrollment Management: Creating a Definition that Works, Director, Analysis, Planning, & Assessment, Pittsburg State University, http://www.educationalpolicy.org/pdf/SEM%20Guide.pdf.