STRATEGIC DECISION SUPPORT SYSTEM BASED HYBRID MODELS FOR COLLEGES ENROLLMENT CAPACITY PLANNING: DESIGN & IMPLEMENTATION

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Abstract: This paper proposes a Hybrid Strategic Decision Support System (H-SDSS) for colleges' enrollment capacity planning. Three hybrid subsystems are combined for executing the task of decision making processes. The system includes students' track specified model, colleges' enrollment model and students' capacity forecast model. Data mining knowledge based rules and goal programming based methods are used for building the system. This H-SDSS is expected to help university decision makers for solving problems related to strategic decisions for enhancing university students' admission and enrollment capacity planning to satisfy future of higher educational demands as well as labor market needs.

Keywords: Strategic Decision, DSS, Goal programming, knowledge base rule, Data mining.

Introduction

DSS is an interactive computer-based system intended to help decision makers use communications technologies, data and documents, knowledge and models to identify and solve problems, to complete decision process tasks, and to make decisions. DSS enhances a person and group's ability to make decisions. DSS can be differentiated by the level of decision (Gutierrez, 2008): Strategic where the decision can be taken for two to five years, Tactical; where a decision can be taken within a few months up to two years, Operational; where a decision can be dealt within a few days or a few months, and Dispatching; where a decision can be taken just for some hours.
Standalone DSSs are limited performance and lacks efficiency specially with the fast growing in developed technology. The Hybrid DSS can solve these problems and improve the overall system performance. Hybrid DSS has been used in many specific areas and application such as medical care (Berner, 2009), finance (Kotsiantis, 2006), and architecture (Simmons, 2008). However, the literature did not cover well the HDSS in the area of Higher Education Management. The work proposed in this paper suggested a novel design and implementation for a hybrid strategies DSS. The architecture combines data mining approaches (Han & Kamber, 2006) as well as goal programming (Orumie & Ebong, 2014). This is expected to satisfy Higher Education institutions' decision makers for solving problems related to students' college admission and enrollment effectively and improving universities of achieving their goals for getting optimal capacity that satisfying their future needs.
Most of previous work are based on using single model DSS, and this lacks flexibility, adaptability, and capability. This paper introduces a novel H-SDSS based hybrid subsystem and integrated models for design and implementation for Colleges Enrollment Capacity Planning. The rest of the paper explains the following sections: literature survey, the architecture of the proposed H-SDSS system, the applied case study data resources and system implementation, the H-SDSS system results, and the conclusions, respectively.

Literature Survey

DSSs vary greatly in application and complexity, but they all share specific features. A typical DSS has four components (Power, 2008): data management, model management, knowledge management and user interface management. Decision making in a complex, dynamically changing environment is a difficult task that requires new techniques of computational intelligence for building adaptive, hybrid intelligent decision support systems (HIDSS). These hybrid systems combine several of Knowledge-Based Systems into one system (Kendal & Creen, 2007). They achieve this combination either in a loose coupling, e.g. different modules in the same system use different methods, or in a tight coupling - methods are mixed at a low level, e.g. fuzzy neural networks or fully integrated systems. These are the most promising among standalone DSS. Since, they integrate the advantages of all the methods combined, e.g. dealing with both data and expert rules, using both statistical formulas and heuristics or hints.

Authors (Fong & etal, 2009) proposed a hybrid model of neural network and decision tree classifier that predicts the likelihood of which university a student may enter, by analyzing his academic merits, background and the university admission criteria from that of historical records. Authors (Kasabov & etal, 2016) proposed hybrid intelligent decision support systems and applications for risk analysis and discovery of evolving economic clusters in Europe. Authors (Chen & etal, 2012) proposed a hybrid DSS combining several data mining techniques using an improved weighted majority voting scheme (iWMV). Authors (Mansoul & etal, 2013) proposed a hybrid DSS for application on Healthcare. They used an approach based on using a multi-criteria decision guided by a case-based reasoning (CBR) approach. Authors (Balakrishnan & etal, 2013) developed A hybrid predictive system for retinopathy. They used data mining and case based reasoning (CBR). C5.0 was used to produce the decision tree whereas k-nearest neighbor and Hamming distance algorithms were used to select the three most similar cases for every new case entered into the system.

In this paper, it is proposed to use goal programming method for managing the integrated models subsystem, and using data mining knowledge based for managing the data driven subsystem. Goal programming (GP) is a branch of multi-objective optimization, which in turn is a branch of multi-criteria decision analysis (MCDA). GP is used to perform three types of analysis (Inflibnet , 2016): (1) Determine the required resources to achieve a desired set of objectives, (2) Determine the degree of attainment of the goals with the available resources, (3) Providing the best satisfying solution under a varying amount of resources and priorities of the goals. Data Mining (DM) is the process of collecting, searching through, and analyzing a large amount of data in a database, as to discover patterns or relationships (Han & Kamber, 2006). The most commonly DM methods used in this paper including: student's classification, clustering based on association discovery rules.

Materials and Methods

Figure 1 shows the components of the hybrid SDSS system proposed. The *model management subsystem* works as model driven based DSS, and it includes three integrated models: (1) Tracks Specified model (TSM), (2) Colleges Enrollment Model (CEM) and (3) Capacity Forecast Model (CFM) as explained in details in next sections. The *Data Management subsystem* works as data driven based DSS. The *Knowledge-Base Management Subsystem* can support any of these subsystems. It provides intelligence to augment the decision maker's own. It can be interconnected with the organization's knowledge repository Organizational Knowledge Base. Knowledge can be provided via web servers. Many artificial intelligence methods have been implemented in web development systems which are easy to integrate into the other DSS components as explained in next sections.

User Interface

The *User Interface Subsystem* allows the interaction between the computer and the decision maker. It is used by the user; is part of system; to communicate with and commands the DSS. The web browser provides a familiar and consistent Graphical User Interface (GUI) structure for most DSS. The decision maker; user or manager; can be an individual or a group, depending on who is responsible for the decision, and provides the human intellect. An intermediary allows a manager to benefit form a DSS. For example: University staff assistants have specialized knowledge about management problems and some experience with decision support technology. Expert tool users perform tasks that the problem solver does not have the skill or training to perform. University business analysts have a knowledge of the application area, a formal business administration education and considerable skill in using DSS construction tools. Facilitators control and coordinate the use of software to support the work of people working in groups, and are also responsible for the conduct of workgroups sessions.

The Data Management Subsystem (DMS)

It is connected to several internal and external databases for retrieving the necessarily data required. Five databases are dealt with as shown in Figure 1. (1) Web portal university database is used for retrieving students admitted data such as age, ID, nationality and GPA. (2) The university DB it is used for retrieving the preparatory rules, as explained in (Ragab & etal, 2014). (3) The graduated history DB which help for forecasting, as explained next. (4) The colleges DB used for retrieving enrollment criteria rules explained in (Ragab & etal, 2014). (5) Ministry of higher education DB is used for retrieving the key performance indicators (KPIs) according to future suggested plans that have to be satisfied.

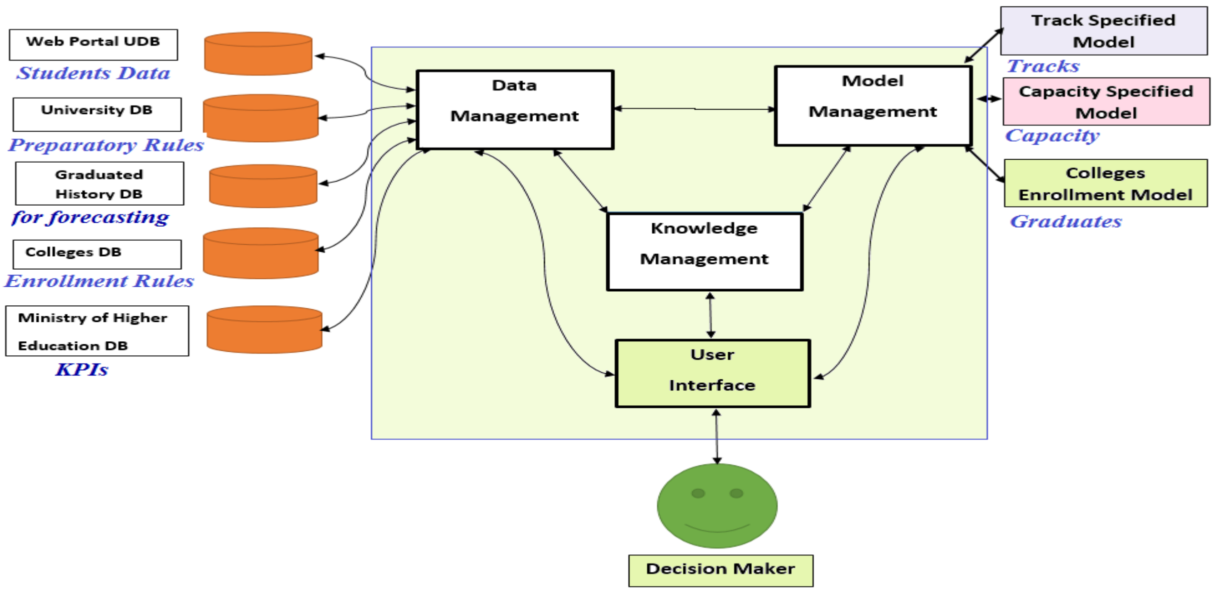

Figure 1. The architecture of the proposed SDSS.

The data Management Subsystem is implemented using data mining (DM) knowledge base rules as explained in (Ragab & etal, 2014). Where, C4.5, PART and Random Forest algorithms gave the highest performance and accuracy with lowest errors. Based on these results, the C4.5 algorithm is used in the implementation. Figure-2 shows a simplified diagram followed for implementing C4.5. A significant cleaning and transformation phase needs to take place so as to prepare the information for DM algorithm. The data we use to construct our DMS subsystem is based on Knowledge Discovery Association Rules. Web usage mining performs mining on student's web data, particularly data stored in logs managed by the web servers. The web log provides a raw trace of the students' navigation and activities on the site. In order to process these log entries and extract valuable patterns that could be used to enhance DMS subsystem and help in system evaluation.

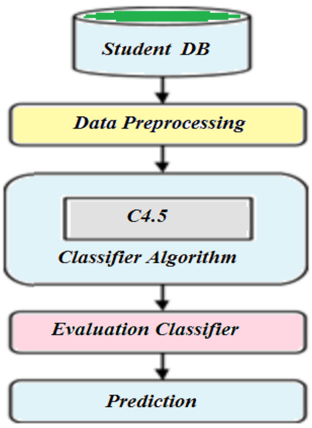

Figure 2. The C4.5 DM algorithm processing steps for implementing DMS.

The Model Management Subsystem (MMS)
It is implemented based on goal programming mathematical model explained in (El-Quliti & etal, 2016). The MMS is consists of three integrated models as follows:

(A) Tracks Specified Model (TSM)
The TSM is used for sorting the preparatory year tracks recommended for fresh students. It contains a sorter and a filter. The sorter used to sort students to several university study tracks available with 60% for Science tracks and 40% for Art tracks. The filter is used to re-arrange students onto two categories. Students who passed all courses successfully will go to college model to be enrolled to suitable colleges. Students who failed in any course are rejected and postponed for services when they are succeeded. The track model executes its' tasks based on the goal programming constrains shown in Table (1) and in the mathematical formulas shown in Appendix-Part (ii).

(B) Colleges Enrollment Model (CEM)

The standard criteria that govern college allocation are based on fulfilling the following four criteria: (1) Success of all preparatory year courses. (2) Minimum score of college prerequisite courses must be satisfied. (3) Weighted Relative Rate must be satisfied. And (4) College capacity must be valid. The CEM contains two internal components; a Classifier and Allocator, respectively. The classifier categorizes students according to their gender and their qualifications. The allocator services students who succeeded in all preparatory year courses and enrolls students into colleges fairly according to the GPA and prerequisite qualified courses stated by specialized colleges. The CEM carries out these tasks based on the goal programming constrains shown in Table (2) and in the Appendix-Part (iii).

(C) Capacity Forecast Model (CFM)

The CFM uses goal programming formulas shown in the appendix to predict the future capacity expected for next upcoming years. For the proposed SDSS forecast purposes, the following goal attributes has been taken into consideration.

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

Relevant parameters and data for the model related to the applied case study explained in next section.

H-SDSS Case Study Data Specifications

Trusted sources of our applied case study input data included the following: (1) the Kingdom of Saudi Arabia (KSA) Ministry of Education Ninth Development Plan (2010-2014) that adopts the drive towards a knowledge based economy through focusing on human development and education (MHE, 2009, 2016). The main challenges of education are improving enrolment rates, reducing dropout rates at all levels of education, and enabling education to meet the demand of labor market. (2) The twenty-five-year plan (AAFAQ) for KSA Higher Education Development (MHE, 2016). (3) The statistical KSA universities data from the web during years 2004-2015 (ISD, 2014 & CDIS, 2016). Applying these data into the proposed system implemented, the results are obtained as explained next section. The mathematical model will cover the main objectives stated in the KSA Plan and that stated in KSA Strategic Plan (AAFAQ). 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. To design the decision variables for the case study applied, it is necessary to represent all different problem attributes as defined 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*.

Table 2: The KPIs input parameters related to the applied case study.

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 enrollment 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: The input data in the year 2015, used as current year in the mode.

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

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

Symbol	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 section, science and engineering)	19,346	21,281	23,409
$F_{g,S}^{y,U}$	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

Relevant parameters and data for the applied case study are collected and presented in Table 2, (MHE, 2016). Table 3 represents the input data in the year 2015; which considered as current year y in the goal programming model. Table 4 represents the input data for different years needed in the mathematical model. Based on these defined attributes and equations, the results obtained are explained in section 6.

H-SDSS System Implementation

The hybrid integrated models subsystem is implemented based on goal programming method (El-Quliti, 2016). The enrollment part is presented in equations (1-57) shown in the Appendix. The graduation part are solved directly using the inequality relations (58-69). Relevant model parameters and data for the applied case study are represented in the Tables (1-4) in the previous sections. Figure 3 shows a simplified flowchart for the algorithm implemented. Details computations are explained in next sections.

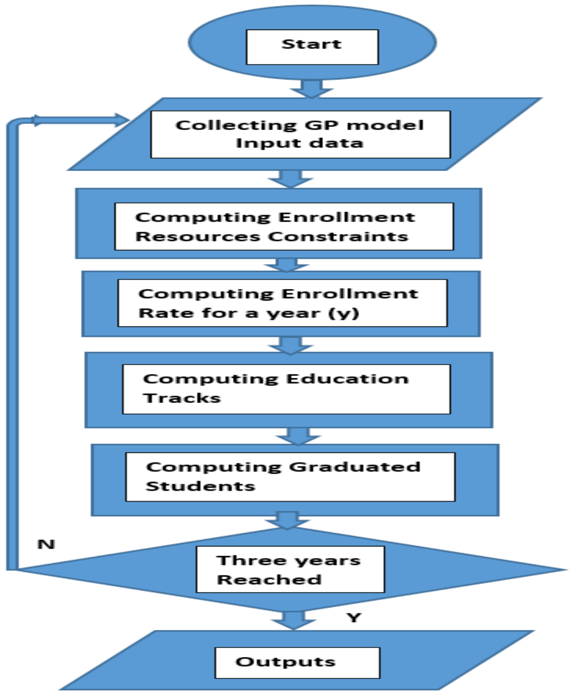

Figure 3. Simplified goal programming followed steps for the H-SDSS algorithm implemented.

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 is more than or equal p_s^y and computed as shown in Appendix-part (ii-A). The percentage of the total number of students enrolled in medical programs to the total number of students enrolled in science and engineering is more than or equal p_m^y and computed as shown in Appendix part (ii-B). The Tracks Specified Model (TSM) executes these functions.

Control Students Enrollments and Graduation Rate

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.
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,
The percentage of total enrollment in higher education regardless of age, to the total population in the age group of 18-23 years $\geq p_p^y$, and the accepted percentage in higher education from high school graduates in the same year $\geq p_h^y$. It is required to increase the enrollment of students in higher education with an average annual growth rate of p_r^y. The percentage of the total number of enrolled girls to the total number of enrolled boys in higher education $\geq p_g^y$. These values are computed as shown in Appendix part (iv). The number of graduates that will be increase with an average annual rate = q_r^y. 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 values are computed as shown in Appendix part (v). The Colleges Enrollment Model (CEM) and the Capacity Forecast Model (CFM) process these tasks.

Results and Discussion

Table 5 and Figure 4 show the predicted number of students enrolled and graduated in the years 2016, 2017 and 2018. Results show that the number of enrollment students increase regularly every year. So that decision makers has to take necessarily steps towards supplying required resources to cover this increase. The number of graduated students also increases regularly every year. This increased value has to be taken into consideration by labor market for offering qualified jobs suitable for the graduates excess. It is also noted that the average number of drop out students (E-G) is increases. This value is high and it should be taken care of by university decision makers to be reduced. And Higher Education Ministry plan recommended dropout rate should be within the limit of 1%.

Table 5: Optimal solution for planning per year (*y*).

#	Meaning	Decision Variable	Year (*y*)		
			2016	**2017**	**2018**
1	Enrolled boys in medical	*EBM*	12,250	13,451	13,907
2	Graduated boys in Medical	*GBM*	7,240	7,965	8,467
3	Enrolled boys in science	*EBS*	54,856	56,612	69,936
4	Graduated boys in science	*GBS*	47,736	49,710	51,639
5	Enrolled girls in medical	*EGM*	9,325	10,244	11,465
6	Graduated girls in medical	*GGM*	6,047	6,651	6,954
7	Enrolled girls in science	*EGS*	46,729	52,044	53,003
8	Graduated girls in science	*GGS*	36,937	38,831	40,638
9	Enrolled boys in arts	*EBA*	34,907	41,629	43,566
10	Graduated boys in arts	*GBA*	29,156	32,071	34,328
11	Enrolled girls in arts	*EGA*	39,666	40,901	43,632
12	Graduated girls in arts	*GGA*	33,144	36,458	39,843

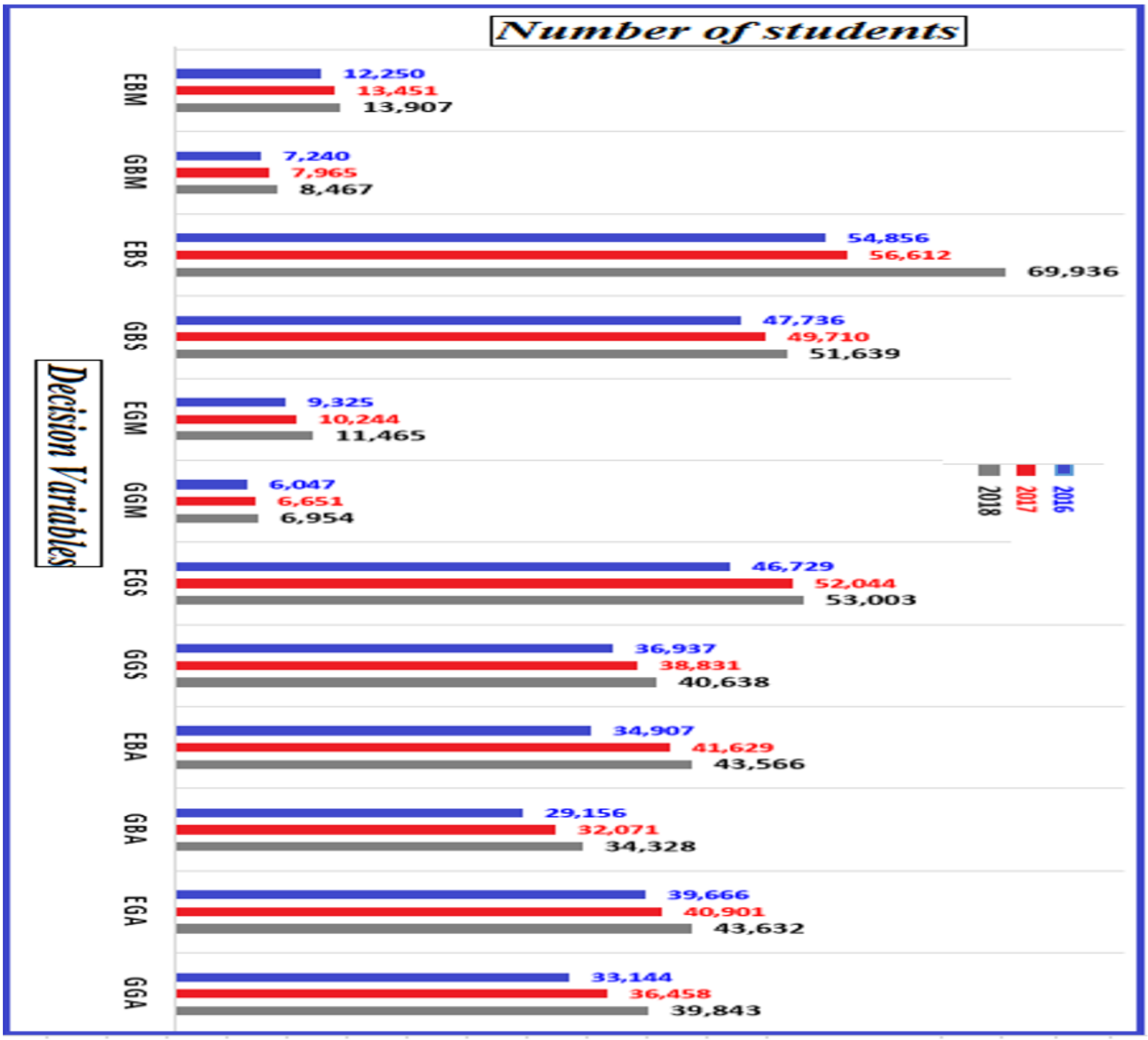

Figure 4. Enrollment and Graduated students predicted w.r.t years 2016-2018.

Conclusion

This paper introduced a new architecture of hybrid strategic decision support system (HSDSS) that can be used efficiently for colleges' enrollment capacity planning. This can help university decision makers for tackling problems related to students' college enrollments as well as to suggest required facilities that are helpful to accommodate increasing future demands and needs. The HSDSS uses goal programming methods for predicting future capacity, as well as data mining knowledge base algorithms for determine students' suitable tracks and college enrollment that satisfying students' desires and university criteria. Results; of the applied case study; show that the number of graduated students increases annually. This can be reflected on labor market needs for offering *Science* related jobs with 60% and *Art* specialist related jobs with 40%, as Ministry of Higher Education in KSA plan recommended. In addition, results show that students' dropout also increases functional to the enrollments and this cause a problem. Hence, university decision makers have to take necessarily solutions to limit this increase, the recommended value hoped to be achieved is 1%.

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Appendix: Goal Programming Model Computing Equations.

i. Steps for computing Enrollment Rate (p_r^y)

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

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

The **nonlinear** constraints is **linearized** by multiplying both sides with the denominator", then the right hand side will represent the number of students.

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

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

ii. Computing Education Tracks

(A) Steps for Computing p_s^y:

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

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

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

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

(B) Steps for Computing p_m^y:

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

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

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

(4) $\sum_{u\in U}\sum_{k=m\in M} x_{E,g,k}^{y,u} + d_{y+15}^- \geq p_m^y . \sum_{u\in U}\sum_{k=s\in S} x_{E,g,k}^{y-1,u}$, y = 1, 2, 3.
(16-18)

(C) Steps for Computing p_h^y.

$\sum_{u\in U}\sum_{j\in J}\sum_{k\in K} x_{E,j,k}^{y,u} + d_{y+18}^{y-} \geq \max [(\frac{1}{5}.p_p^y . N_C^{y-1}), (p_h^y . N_H^{y-1})]$, y = 1, 2, 3
(19-21)

iii. Steps for computing Student-to-Faculty Ratio

(1) $\sum_{u\in U}\sum_{m\in M} x_{E,b,m}^{y,u} - d_{y+21}^+ \leq \frac{1}{t_M} . \beta_M^y . \boldsymbol{F_{b,M}^{y,U}}$, y = 1, 2, 3. (22-24)

(2) $\sum_{u\in U}\sum_{m\in M} x_{E,g,m}^{y,u} - d_{y+24}^+ \leq \frac{1}{t_M} . \beta_M^y . \boldsymbol{F_{g,M}^{y,U}}$, y = 1, 2, 3. (25-27)

Continue Appendix

(3) $\sum_{u\in U}\sum_{s\in S} x_{E,b,s}^{y,u} - d_{y+27}^{+} \le \frac{1}{t_S}.\beta_S^y .\boldsymbol{F_{b,S}^{y,U}}, y = 1, 2, 3.$ (28-30)

(4) $\sum_{u\in U}\sum_{s\in S} x_{E,g,s}^{y,u} - d_{y+30}^{+} \le \frac{1}{t_S}.\beta_S^y .\boldsymbol{F_{g,M}^{y,U}}, y = 1, 2, 3.$ (31-33)

(5) $\sum_{u\in U}\sum_{a\in A} x_{E,b,a}^{y,u} - d_{y+33}^{+} \le \frac{1}{t_A}.\beta_A^y .\boldsymbol{F_{b,A}^{y,U}}, y = 1, 2, 3.$ (34-36)

(6) $\sum_{u\in U}\sum_{a\in A} x_{E,g,a}^{y,u} - d_{36}^{+} \le \frac{1}{t_A}.\beta_A^y .\boldsymbol{F_{g,A}^{y,U}}, y = 1, 2, 3.$ (37-39)

(7) $\sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y,u} - d_{y+39}^{+} \le \frac{1}{t_M}.\beta_U^y .\boldsymbol{F_{b,T}^{y,U}}, y = 1, 2, 3.$ (40-42)

(8) $\sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y,u} - d_{y+42}^{+} \le \frac{1}{t_M}.\beta_U^y .\boldsymbol{F_{g,T}^{y,U}}, y = 1, 2, 3.$ (43-45)

iv. Steps for computing Enrolled Girls-to-Boys Ratio ($\boldsymbol{p_g^y}$)

(1) $\frac{\sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y,u}}{\sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y,u}} + d_{y+45}^{-} \ge \boldsymbol{p_g^y}$, y = 1, 2, 3.

(2) $\sum_{u\in U}\sum_{k\in K} x_{E,g,k}^{y,u} + d_{y+45}^{-} \ge \boldsymbol{p_g^y}. \sum_{u\in U}\sum_{k\in K} x_{E,b,k}^{y,u}$, y = 1, 2, 3. (46-48)

vi. Enrollment Resources Constraints

for 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)

v. Steps for computing number of Graduated Students

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

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

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

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

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

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

