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Designing a Mathematical Model for Allocating Budget to University Research and Educational Goals: A Case Study in Shahed University

Saeed Safari [1], Ahmad Sardari[2], Hossein Sabzian[3*]

1. Assistant Professor of Management Faculty, Shahed University, Tehran, Iran
2. Associate Professor of Management Faculty, Shahed University, Tehran, Iran
3. Master of Management, Shahed University, Tehran, Iran

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Abstract

Institutions of higher education, both public and private, are among the most important institutions of a country. Several economic factors have forced them to act for improving the cost-effectiveness of their activities and the quality of their products (outputs) is strongly expected. Such issues have led universities to focus on profit-making activities and commercialization like manufacturing industries. This propensity is grounded in the fact that manufacturing industries working under an efficient management system can produce very high-quality products. As a matter of fact, there is no such a model for academic contexts. Therefore, this paper is aimed at offering such a model. The coefficients and constants used in this model have all been extracted based on analyzing research and educational aspects of Shahed University. The proposed model is a lexicographic model which has thirty six decision variables that are broken down into two classes of university sources variables (fifteen) and university products variables. The model also includes forty nine goals, seven structural constraints and twenty integer variables. At the end of the paper, the current situation is compared with the recommended one and it shows that many of the variables are suboptimal except variables of research and educational officials (S_9), graduate (P_7) and PhD (P_9) night course students number. The comprehensiveness of this model enables managers to plan the smallest research and educational activities and the solutions can be used by managers as applied guidelines.

Keywords:

Quantitative approach, Resource allocation, Integer lexicographic goal programming, Manufacturing industries.

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* Corresponding Author, Tel: +98 9166452462 Email: sabzeyan@yahoo.com

Introduction

So many researches have been conducted on resource allocation in academic environments from 1960 onwards (Williams, 2005). The university budget constraint is the most important reason for this trend. Budget allocation among conflicting plans is principally a very arduous work. As a result, designing quantitative models that aid managers to solve such a problem has become one of the most attractive interests of university strategists. Since early 1990's, many universities in Britain were corporatized and subsequently followed by Malaysian universities. Corporatization allows universities to borrow money, enter businesses, set up companies and acquire investment shares. Universities are expected to raise tuition fees, increasing enrollment of students, conducting consultancies for industry and government, running short-term courses to meet the needs of private sectors, and renting out facilities. These changes are aimed at developing alternative funding sources for higher education and reducing the financial dependencies on the government. Supporters of the corporatization argue that, with these changes, universities will attain better financial and administrative autonomy. By offering attractive salary packages to academic staff, corporatized university may be able to prevent the brain drain of academicians to the private sector. Majority of the models proposed regarding university resource allocation has not taken such issues into account and many of them suffer a very limited application. Some problems related to these models entail lack of actual implementation such as the inability of some of them to abstract the multiple and conflicting goals inherent in the academic environment, the over-complexity of some of the models, and the failure of a majority of them to consider the cognitive limitation of the academic decision makers and the nature of the decision process itself (Schroeder, 1973).

Literature Review

In 1987, using a survey of one hundred and forty six articles, White (1987) showed that the available models can be implemented in higher education administration. In a research conducted in 2001, Romero and caballero emphasized the application of quantitative models for solving resource allocation problems of the universities. These two researchers, in a study conducted in 2006, could design an interactive goal programming

model. By this model, managers could overcome so many of the resource allocation challenges. One of the outstanding features of this model is that it enabled managers to cope with the unexpected and uncertain environmental phenomena smartly (Caballero et al., 2006). Hopkins (1971) developed a cost simulation model in which the budget was considered as an output of the model rather than input. On the other hand, Schroeder designed a model in which the budget for planning future years was taken into account as an input (Schroeder, 1973). Basu and Pal used a goal programming model for allocating the budget within the existing academic units in a university in future planning period, their model was able to allocate the budget for attainment of the desired level of teaching staff, non-teaching staff and research fellows (Basu & Pal, 2006). Nopiah and associates developed a comprehensive model for university budget planning. The comprehensiveness of this model empowered planners to cover different parts of an educational system and track the resource allocation flow more precisely (Nopiah et al., 2007). In a long-range research conducted about university resource allocation systems, Pal and Sen could develop an efficient goal programming model for right resource allocation. This model has considered the resource trade-off in the educational systems so well (Bijay Baran & Shymal, 2008). Dylan Jones (2011) also developed a new pattern for sensitivity analysis of resource allocation goal programming models in his studies. Jones and Tamiz (2010) have represented the goal programming growing trend up to the late 2000s in Figure 1.

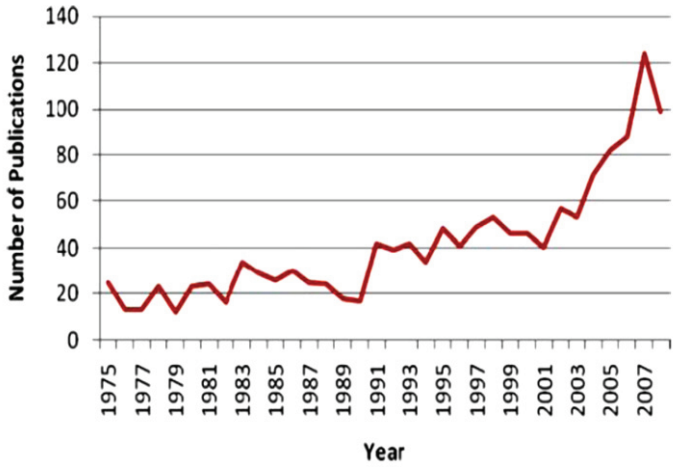

Figure 1. Goal programming publications in period 1975-2008.

This paper is aimed at developing an integer lexicographic goal programming model for university budget allocation by considering it as a manufacturing system.

Model Formulation

Integer lexicographic goal programming (ILGP) model has been comprehensively elucidated by Jones and Tamiz (2010). The generic form of ILGP is shown as:

$$Min\ z = \sum_{i=1}^{m} P_i \left(d_i^- + d_i^+\right)$$

$$st:$$

$$p_i)\sum_{j}^{n} a_{ij} x_j + d_i^- - d_i^+ = b_i$$

$$x_j, d_i^+, d_i^- \geq 0 \quad , \quad i = 1,2,...,m$$

$$j = 1,2,.....n$$

Where X_j is representative of decision variables, d_i^- represents negative deviation variables, d_i^+ indicates positive deviation variables p_i shows pre-emptive priority factors. In the lexicographic model, the pre-emptive priority factors (p_i) have the relationship of $P_K \succ\succ\succ P_{K+1}$ where "$\succ\succ\succ$" implies much greater than and that is the set of goals at the highest priority level (P_1) must be achieved to the extent possible before the set of goals at the next priority level (P_2) is considered**.**

Decision Variables

In this research, decision variables are decomposed into two classes of university sources **(**$\sum_{i=1}^{15} s_i$ **)** and university products **(**$\sum_{i=1}^{21} p_i$ **).** These variables are represented in Table 1.

Table 1: Research and educational decision variables based on space of the University

Decision variables			
	university products (P_j)		university sources (S_j)
Number of bachelor fields	P_1	Number of full professors	S_1
Number of master fields	P_2	Number of associate professors	S_2
Number of PhD fields	P_3	Number of assistant professors	S_3
Number of medicine fields	P_4	Number of lecturers	S_4
Number of residence fields	P_5	Number of full professors tuition hours	S_5
Number of daytime bachelor students	P_6	Number of associate professors tuition hours	S_6
Number of night time bachelor students	P_7	Number of assistant professors tuition hours	S_7
Number of daytime master students	p_8	Number of lecturers tuition hours	S_8
Number of night time master students	p_9	Number of research and educational staff	S_9
Number of daytime PhD students	p_{10}	Number of small-scale researches	S_{10}
Number of night time PhD students	p_{11}	Number of medium-scale researches	S_{11}
Number of medicine students	p_{12}	Number of large-scale researches	S_{12}
Number of residence students	p_{13}	Number of computers allocated to research and educational affairs	S_{13}
Number of published books	p_{14}	Number of reference books	S_{14}
Number of published research and scientific journals	p_{15}	Number of non- reference books	S_{15}
Number of university external projects	p_{16}		
Number of inventions	p_{17}		
Number of conferences	p_{18}		
Number of papers published by faculties	p_{19}		
Number of book titles	p_{20}		
Number of research and scientific journals titles	p_{21}		

During interviewing with research and educational managers of Shahed university, it became clear that small-scale researches (SSR) refer to those researches that cost less than 2000000 Tomans ($SSR < 2000000$). Medium-scale researches (MSR) refer to those researches whose costs are equal to 2000000 and less than 5000000 Tomans ($2000000 \le MSR < 5000000$)

and large-scale researches (LSR) are referred to those researches whose costs are at least 5000000 Tomans ($5000000 \le LSR$).

Technological Coefficients and Constants

Technological coefficients and constants were extracted via mathematical investigations of Shahed University "as is" structure. This information is represented in Table 2.

Table 2. Representation of all technological coefficients and constants

Value	Description	Coefficient symbol	Value	Description	Coefficient symbol
600000	Average cost of per computer	β_{13}	900000	Average annual tuition fees of bachelor students whose fields take night time students	a_1
30000	Average cost of per reference book	β_{14}	2472695.03	Average annual tuition fees of master students whose fields take night time students	a_2
12000	Average cost of per non-reference book	β_{15}	5000000	Average annual tuition fees of PhD students whose fields take night time students	a_3
5370.69	Average cost of publishing per book	λ_1	8850	Average price of per book	a_4
600	Average cost of publishing per journal	λ_2	700	Average price of per journal	a_5
4750000	Average cost of holding per conference	λ_3	17483051.45	Average price of per university external project	a_6
38.52%	percentage of bachelor students needing supervision (those who have dissertation)	κ_1	0	Average price of per invention	a_7
100%	percentage of master students needing supervision	κ_2	6000000	Average price of per conference held by university	a_8
100%	percentage of PhD students needing supervision	k_3	2	Average number of papers published by faculties	γ_1
100%	percentage of Medicine students needing supervision	k_4	102.72	Average annual supervision on per bachelor student	v_1
100%	percentage of residence students needing supervision	k_5	189.76	Average annual supervision on per master student	v_2
256	Average number of classes allocated to the bachelor courses in each year	η_1	179.84	Average annual supervision on per PhD student	v_3
134.08	Average number of classes allocated to the master courses in each year	η_2	58.88	Average annual supervision on per Medicine student	v_4

96	Average number of classes allocated to the PhD courses in each year	η_3	139.84	Average annual supervision on per Residence student	ν_5
224	Average number of classes allocated to the medicine courses in each year	η_4	28800000	Average annual salary of per full professor	β_1
32	Average number of classes allocated to the residence courses in each yea	η_5	26400000	Average annual salary of per associate professor	β_2
640	Average number of Credit hour for per bachelor course in each year	μ_1	22800000	Average annual salary of per assistant professor	β_3
344.96	Average number of Credit hour for per master course in each year	μ_2	13200000	Average annual salary of per lecturer	β_4
192	Average number of Credit hour for per PhD course in each year	μ_3	28000	Average tuition cost of per full professor in an hour	β_5
640	Average number of Credit hour for per Medicine course in each year	μ_4	21000	Average tuition cost of per associate professor in an hour	β_6
93.12	Average number of Credit hour for per Residence course in each year	μ_5	15000	Average tuition cost of per assistant professor in an hour	β_7
		Constants	13000	Average tuition cost of per lecturer in an hour	β_8
1183	Total number of computers	δ_1	900000	Average annual salary of per research and educational staff	β_9
32237	Total number of reference books	δ_2	1625000	Average cost of per small-scale research	β_{10}
99589	Total number of non- reference books	δ_3	2872354.14	Average cost of per medium-scale research	β_{11}
304500000	Total annual cost of database supporting	ω_1	8817500	Average cost of per large-scale research	β_{12}
777750000	Total tuition cost of invited professors in one year.	ω_2			

Goals and Target Levels

Achievement of the organization's goals is the bedrock of resource allocation decisions. Like other organizations, higher education institutes want to attain a series of goals. Since the factual mission of each university

is to advance the science and open up new research fields, such organizations have several similar goals. Although such goals differ in terms of quantity, they are the same in terms of type. The most common and widespread university research and educational goals were elicited by reviewing some of the available texts of university resource allocation. Texts used include New York State University budget allocation report (NY Publications, 1998), Eastern Washington University budget allocation strategic model (EW Publications, 2003), Mary Land University budget allocation report (MU publications, 2005), Dimmini and Kwak research (1987). UK educational performance indicators review (HEFCE Publications, 2005), Canada University association report (2006), Australia Bureau of Statistics (2007), UNESCO report (1999), Denmark Education Ministry (2010), China national report (2008).

After goals had been elicited and then affirmed by scholars, for the purpose of determining their conformity with Shahed University research and educational goals, they were discussed with research and educational managers that finally they affirmed some of goals as theirs and added some new ones. In the next step, throughout some sessions the target value (b_i) of each goal was precisely specified by managers. Since the respondents were six people, those goals expressed in the form of ratio were merged by geometric mean ($\mu_G = (X_1 \times X_2 \times X_3 \times ... \times X_N)^{\frac{1}{N}}$) and those ones expressed in the form of non-ration were merged by arithmetic mean ($\mu = \frac{\sum_{i=1}^{N} x_i}{N}$). Final goals are represented in Table 3.

Table 3: List of research and educational goals of Shahed University

Mathematical Representation	Goals	No.
$\frac{p_2}{p_1} \geq \frac{50}{37}$	University wants the ratio of masters courses to bachelor ones to be at least 50:37	1
$\frac{p_3}{p_2} \geq \frac{12}{47}$	University wants the ratio of PhD courses to Master ones to be at least 12:47	2
$\frac{p_5}{p_4} \geq \frac{8}{2}$	University wants the ratio of Residence courses to Medicine ones to be at least 8:2	3

$P_6 + P_7 = 3850$	University wants bachelor students total number to be exactly equal to 3850	4
$P_8 + P_9 \geq 2275$	University wants master students total number to be at least 2275	5
$P_{10} + P_{11} \geq 146$	University wants PhD students total number to be at least 146	6
$P_{12} \geq 458$	University wants Medicine students total number to be at least 458	7
$P_{13} \geq 84$	University wants Residence students total number to be at least 84	8
$P_7 = 0$	University wants bachelor night time students total number to be exactly equal to 0	9
$P_9 \geq \frac{1}{2} P_8$	University wants master night time students total number to be at least half of master daytime students total number.	10
$P_{11} = 0$	University wants PhD night time students total number to be exactly equal to 0	11
$\frac{\sum_{i=6}^{11} p_j}{\sum_{i=12}^{13} p_j} \leq \frac{11}{1}$	University wants ratio of bachelor, master and PhD Students total number on medicine and Residence students total number to be at most 11:1	12
$\frac{\delta_1 + s_{13}}{\sum_{i=8}^{9} p_j + \sum_{i=10}^{11} p_j + p_{13}} \geq \frac{2}{3}$	University wants the ratio of computers allocated to research and educational affairs to post-graduate students total number (i.e., bachelor, master and PhD Students) to be at least 2:3	13
$\delta_1 + s_{13} \geq 1200$	University wants computers allocated to research and educational affairs number to be at least 1200	14
$\frac{\delta_2 + s_{14}}{\sum_{i=6}^{13} p_j} \geq \frac{11}{2}$	University wants the ratio of reference books to students total number to be at least 11:2	15
$\delta_2 + s_{14} \leq 35027$	University wants reference books total number to be at most 35027:	16
$\frac{p_{20}}{\sum_{i=1}^{4} s_j} = \frac{1}{20}$	University want ratio of published books to faculties to be exactly equal to 1:20	17
$\frac{\gamma_1 p_{19}}{\sum_{i=1}^{4} s_j} \geq \frac{4}{2}$	University wants the ratio of published papers to faculty members to be at least 4:2	18

$\frac{\gamma_1 p_{19}}{\sum_{i=10}^{12} s_j} \geq \frac{6}{3}$	University wants the ratio of published papers to internal researches (i.e.,. small, medium and large-scale researches)to be at least 6:3	19
$p_{21} = 6$	University wants the journal titles to be exactly equal to 6	20
$\frac{p_{17}}{\sum_{i=10}^{12} s_j} \geq \frac{1}{15}$	University wants the ratio of inventions to researches to be at least 1:15	21
$\frac{\sum_{i=8}^{9} p_j + \sum_{i=10}^{11} p_j + p_{13}}{s_{12}} \geq \frac{40}{1}$	University wants the ratio of the post-graduate students to large-scale researches to be at least 40:1	22
$\frac{s_1}{\sum_{i=1}^{4} s_j} \geq \frac{1}{22}$	University wants ratio of full professors to faculty members to be at least 1:22	23
$\frac{s_2}{\sum_{i=1}^{4} s_j} \geq \frac{3}{19}$	University wants ratio of associate professors to faculty members to be at least 1:22	24
$\frac{s_3}{\sum_{i=1}^{4} s_j} \geq \frac{6}{9}$	University wants ratio of assistant professors to faculty members to be at least 1:22	25
$\frac{s_4}{\sum_{i=1}^{4} s_j} \leq \frac{5}{20}$	University wants ratio of lecturers to faculty members to be at least 1:22	26
$\frac{s_9}{\sum_{i=1}^{4} s_j} \geq \frac{10}{13}$	University wants ratio of staff to faculty members to be at least 1:22	27
$p_{17} \geq 6$	University wants invention number to be at least 6	28
$p_{16} \geq 30$	University wants university external projects number to be at least 30	29
$s_9 \leq 278$	University wants staff number to be at most 278	30
$s_{10} \geq 10$	University wants small-scale researches number to be at least 10	31
$s_{11} \geq 12$	University wants medium-scale researches number to be at least 12	32
$s_{12} \geq 50$	University wants large-scale researches number to be at least 50	33
$p_1 = 36$	University wants bachelor courses number to be exactly equal to 36	34

$p_{18} \geq 4$	University wants to hold at least 4 conferences in a year	35
$\alpha_1 p_7 + \alpha_2 p_9 + \alpha_3 p_{11} + \alpha_4 p_{14} + \alpha_5 p_{15} + \alpha_6 p_{16} + \alpha_7 p_{17} + \alpha_8 p_{18} \geq 2000000000$	University wants the income of its research and educational activities to be at least 2000000000 tomans	36
$\frac{s_{12}}{\sum_{i=10.}^{12} s_j} \geq \frac{3}{1}$	University wants the ratio of large-scale researches to all researches to be at least 3:1	37
$\frac{\delta_3 + s_{15}}{\sum_{i=6}^{13} p_j} \leq \frac{16}{1}$	University wants the ratio of non-reference books to students to be at most 16:1	38
$s_5 + s_6 + s_7 + s_8 \leq 4500$	University wants the all faculties tuition time to be at most 4500 hours in a year.	39
$\frac{[\sum_{i=1}^{5}\sum_{j=1}^{5}\eta_i \mu_i p_j] + [\kappa_1 \nu_1 \sum_{j=6}^{7} p_j + \kappa_2 \nu_2 \sum_{j=8}^{9} p_j + \kappa_3 \nu_3 \sum_{j=10}^{11} p_j + \kappa_4 \nu_4 p_{12} + \kappa_5 \nu_5 p_{13}]}{s_1} \geq 320$	University wants the credit (teaching) and supervising time of each full professor to be at least 320 hours in a year	40
$\frac{[\sum_{i=1}^{5}\sum_{j=1}^{5}\eta_i \mu_i p_j] + [\kappa_1 \nu_1 \sum_{j=6}^{7} p_j + \kappa_2 \nu_2 \sum_{j=8}^{9} p_j + \kappa_3 \nu_3 \sum_{j=10}^{11} p_j + \kappa_4 \nu_4 p_{12} + \kappa_5 \nu_5 p_{13}]}{s_2} \geq 384$	University wants the credit (teaching) and supervising time of each assistant professor to be at least 384 hours in a year	41
$\frac{[\sum_{i=1}^{4}\sum_{j=1}^{4}\eta_i \mu_i p_j] + [\kappa_1 \nu_1 \sum_{j=6}^{7} p_j + \kappa_2 \nu_2 \sum_{j=8}^{9} p_j + \kappa_3 \nu_3 \sum_{j=10}^{11} p_j + \kappa_4 \nu_4 p_{12}]}{s_3} \geq 448$	University wants the credit (teaching) and supervising time of each assistant professor to be at least 448 hours in a year	42
$\frac{[\eta_1 \mu_1 p_1] + [\kappa_1 \nu_1 \sum_{j=6}^{7} p_j]}{s_4} \geq 512$	University wants the credit (teaching) and supervising time of each lecturer to be at least 320 hours in a year	43
$p_{14} = 1000 p_{20}$	university wants published books versions number of each book title to be exactly equal to 1000 versions of that title	44
$p_{15} = 6000 p_{21}$	University wants published journal versions number of each journal title to be exactly equal to 6000 versions of that title in a year.	45
$p_2 \geq 49$	University wants master courses number to be at least 49.	46
$p_3 \leq 9$	University wants PhD courses number to be at least 9.	47
$p_4 \geq 3$	University wants medicine courses number to be at least 3.	48
$p_5 \leq 8$	University wants residence courses number to be at most 8.	49

Systematic Constraints

Systematic constraints of research and educational goals of Shahed University are shown in Table 4.

Table 4: Systematic constraints

$\sum_{i=1}^{15}(\beta_i s_i)+\lambda_1 P_{14}+\lambda_2 P_{15}$ $+\lambda_3 P_{18}+\omega_1+\omega_2 \le 16647991600$	All of the budget allocated to research and educational affairs (i.e.,. budget allocated to salary, tuition cost, internal projects, computer purchasing, reference and non-reference books, database supporting, invited professors tuition cost, book and journal publishing cost)must not exceed 16647991600	1
$\sum_{i=10}^{12}(\beta_i s_i) \le 750000000$	All the budget allocated to internal researches must not exceed 750000000	2
$p_6+p_7 \ge 10p_1$	University wants the bachelor students total number to be at least tenfold of bachelor courses total number	3
$p_8+p_9 \ge 6p_2$	University wants the master students total number to be at least sixfold of master courses total number	4
$p_{10}+p_{11} \ge 4p_3$	University wants the PhD students total number to be at least quadruplicate of PhD courses total number	5
$p_{12} \ge 10p_4$	University wants the Medicine students total number to be at least tenfold of Medicine courses total number	6
$p_{13} \ge 4p_5$	University wants the Residence students total number to be at least quadruplicate of Residence courses total number	7

The lexicographic form of goal programming is used as the model of this paper. In this model, goals are ordinally ranked so it is clear-cut that the first goal (g_1) must be attained before the second one (g_2). It can be shown by following relation: $g_1 \succ\succ\succ g_2 \succ\succ\succ g_k$

Model Designing

After decision variables and hard constraints are identified and goals and their target levels are specified and ranked, model can be designed. Information regarding building blocks of the model and its entire form are presented in Table 5 and appendix respectively.

Every mathematical model possesses specific statistical features. These features are represented in Table 6.

Table 6: Model statistical features

integer variables number	rows number	49	goal constraints	36	decision variables	Integer lexicographic goal programming	Kind[1]
20	58	7	hard constrains	134	total variables	MIN	direction

Solving the Model

After designing the model, it was solved by Lingo 11 Software. The solutions are presented in Table 7**.**

Table 7: Model Solutions

250.6875								Objective function value
solution	description	Variable symbol	solution	description	Variable symbol	Deviation Value(***Dv$_i$***)	Deviation Kind (***ND$_i$, PH$_i$***)	Deviated goals (***Dgi***)
278	Number of research and educational staff	S_9	17	Number of full professors	S_1	213	ND_4	g_4
10	Number of small-scale researches	S_{10}	57	Number of associate professors	S_2	30.68	ND6	g_6
11	Number of medium-scale researches	S_{11}	240	Number of assistant professors	S_3	1	ND32	g_{32}
62	Number of large-scale researches	S_{12}	46	Number of lecturers	S_4	0.253	. ND40	g_{40}
6845	Number of computers allocated to research and educational affairs	S_{13}	0	Number of full professors tuition hours	S_5	0.253	ND41	g_{41}
2790	Number of reference books	S_{14}	0	Number of associate professors tuition hours	S_6	0.253	ND42	g_{42}
5616	Number of non-reference books	S_{15}	0	Number of assistant professors tuition hours	S_7	4	PD47	g_{47}
			0	Number of lecturers tuition hours	S_8	1	ND48	g_{48}

1. Variant

solution	description	Variable symbol	solution	description	Variable symbol	solution	description	Variable symbol
36000	Number of published research and scientific journals	p_{15}	1516	Number of daytime master students	p_8	36	Number of bachelor fields	P_1
30	Number of university external projects	p_{16}	759	Number of night time master students	p_9	49	Number of master fields	P_2
6	Number of inventions	p_{17}	115	Number of daytime PhD students	p_{10}	13	Number of PhD fields	P_3
4	Number of conferences	p_{18}	0	Number of night time PhD students	p_{11}	2	Number of medicine fields	P_4
720	Number of papers published by faculties	p_{19}	458	Number of medicine students	p_{12}	8	Number of residence fields	P_5
18	Number of book titles	p_{20}	90	Number of residence students	p_{13}	3637	Number of daytime bachelor students	P_6
6	Number of research and scientific journals titles	p_{21}	18000	Number of published books	p_{14}	0	Number of night time bachelor students	P_7

Conclusion

Collocating current "as is" situation and recommended "to be" situation is a very useful way for shedding some light on the gap between current situation and targeted one. This comparison is presented in Table 8.

Table 8: Direct comparison of current situation and targeted situation

Recommended situation	Current situation	variables		Recommended situation	Current situation	variables		Recommended situation	Current situation	variables	
115	105	Number of daytime PhD students	P_{10}	6845	1183	Number of computers allocated to research and educational affairs	S_{13}	17	11	Number of full professors	S_1
0	0	Number of night time PhD students	P_{11}	2790	32237	Number of reference books	S_{14}	57	29	Number of associate professors	S_2
458	419	Number of medicine students	P_{12}	5616	99859	Number of non-reference books	S_{15}	240	214	Number of assistant professors	S_3

90	61	Number of residence students	P_{13}	36	37	Number of bachelor fields	P_1	46	44	Number of lecturers	S_4
18000	13000	Number of published books	P_{14}	49	47	Number of master fields	P_2	0	423	Number of full professors tuition hours	S_5
36000	30000	Number of published research and scientific journals	P_{15}	13	9	Number of PhD fields	P_3	0	846	Number of associate professors tuition hours	S_6
30	20	Number of university external projects	P_{16}	2	2	Number of medicine fields	P_4	0	2100	Number of assistant professors tuition hours	S_7
6	4	Number of inventions	P_{17}	8	7	Number of residence fields	P_5	0	861	Number of lecturers tuition hours	S_8
4	2	Number of conferences	P_{18}	3637	3803	Number of daytime bachelor students	P_6	278	278	Number of research and education al staff	S_9
720	596	Number of papers published by faculties	P_{19}	0	0	Number of night time bachelor students	P_7	10	4	Number of small-scale researches	S_{10}
18	13	Number of book titles	P_{20}	1516	1234	Number of daytime master students	P_8	11	14	Number of medium-scale researches	S_{11}
6	5	Number of research and scientific journals titles	P_{21}	759	564	Number of night time master students	P_9	62	2	Number of large-scale researches	S_{12}

University goals are achieved with a deviation equal to 250.6875 units. Among all of the goals, only the fourth goal (g_4) is underachieved to 30.68 unites, the sixth goal (g_6) is underachieved to 30.68 units, the thirty second goal (g_{32}) is underachieved to 1 unit, each of the fortieth (g_{40}), forty first (g_{41}) and forty second goals (g_{42}) is underachieved to 0.253, the forty seventh goal (g_{47}) is overachieved to 4 units and the forty eighth goal (g_{48}) is underachieved to 1 unit. With regard to such unwanted deviations and the gap between current situation and recommended one, it can be said that university has eleven full professors up to this time (2011), if it wants to achieve its goals, it should have seventeen full professors in next year (17) so it needs six more full professors.

University has twenty nine associate professors up to this time (2011), if it wants to achieve its goals, it should have fifty seven associate professors in next year (2012) so it needs twenty eight associate professors. University has two hundred fourteen assistant professors up to this time (2011), if it wants to achieve its goals, it should have two hundred forty assistant professors in next year (2012) so it needs twenty six assistant professors. University has forty four lecturers up to this time (2011), if it wants to achieve its goals, it should have forty six lecturers in next year (2012) so it needs two lecturers.

Tuition hour numbers of full professors, associate professors, assistant professors and lecturers are respectively 423, 846, 2100, 861 hours in a year. If university is going to attain its goals, it must reduce this number to 0. So university does not need faculty members' tuition in next year.

University has two hundred seventy eight staff up to this time (2011), if it wants to achieve its goals in the next year, it must maintain this number. So this number is optimal and should not be changed at all. Up to this time (2011), university has conducted four small-scale, fourteen medium-scale and two large-scale researches. If it wants to attain its goals in 2012, it should conduct ten small-scale, eleven medium-scale and sixty two large-scale researches. University has allocated 1183 computers to research and educational affairs up to this time (2001). If it wants to attain its goals in 2012, it must purchase 6845 computers. University has 32237 reference books up to present time. If it wants to attain its goals in 2012, it must purchase 2790 reference book versions. University has 99859 non-reference books up to present time. If it wants to attain its goals in 2012, it must purchase 5616 non-reference book versions.

University has thirty seven bachelor fields up to present time. If it wants to attain its goals in 2012, it must have thirty six fields in this level. So university has one extra field in this level. University has forty seven master fields up to present time. If it wants to attain its goals in 2012, it must have forty nine more fields in this level. So university needs two fields in this level. University has nine PhD fields up to present time. If it wants to attain its goals in 2012, it must have thirteen fields in this level. So university needs four more fields in this level. University has two medicine fields up to present time. If it wants to attain its goals in 2012, it must preserve this number. So this number is optimal and should not be changed at all. University has nine residence fields up to present time. If

it wants to attain its goals in 2012, it must have eight fields in this level. So the university needs one field in this level.

University has 3803 daytime bachelor students up to the present time. If it wants to attain its goals in 2012, it must have 3606 daytime bachelor students. So university has 218 extra daytime bachelor students. University has no night time bachelor student up to present time. If it wants to attain its goals in 2012, it must not have any night time bachelor student. So this is optimal and should not be changed at all. University has 1234 daytime master students up to present time. If it wants to attain its goals in 2012, it must have 1516 daytime bachelor students. So university needs 282 daytime master students. University has 564 night time master student up to present time. If it wants to attain its goals in 2012, it must have 759 night time master students. So university needs 195 night time master students. University has 105 daytime PhD students up to present time. If it wants to attain its goals in 2012, it must have 115 daytime PhD students. So university needs ten daytime PhD students. University has no night time PhD student up to present time. If it wants to attain its goals in 2012, it must not have any night time PhD student. So this is optimal and should not be changed at all.

University has 419 medicine students up to present time. If it wants to attain its goals in 2012, it must have 458 medicine students. So university needs thirty nine daytime PhD students. University has sixty one residence students up to present time. If it wants to attain its goals in 2012, it must have ninety medicine students. So university needs twenty nine daytime PhD students.

University has published thirteen book titles in this year. If it wants to attain its goals in the next year, it should publish eighteen book titles. University has published five journal titles in this year. If it wants to attain its goals in the next year, it should have six journal titles. So university needs one new journal title. University has published 13000 book versions up to present time. If it wants to attain its goals in the next year, it should publish 18000 book versions. University has published 30000 journal versions up to the present time. If it wants to attain its goals in the next year, it must publish 36000 book versions.

University has conducted twenty external projects up to the present time. If it wants to attain its goals in the next year, it must do thirty

external projects. University has had four inventions up to the present time. If it wants to attain its goals in the next year, it must have six inventions. University has held two conferences up to the present time. If it wants to attain its goals in the next year, it must hold four conferences. University faculty members have published 596 papers up to the present time. If university wants to attain its goals in the next year, its faculty members must publish 720 papers.

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Appendix

Model building blocks

Unwanted Deviation (ND_i, PD_i)	**Goal Equation**	**Goal** (g_i)
ND_1	$37P_2 - 50P_1 + ND_1 - PD_1 = 0$	1
ND_2	$47P_3 - 12P_2 + ND_2 - PD_2 = 0$	2
ND_3	$2P_5 - 8P_4 + ND_3 - PD_3 = 0$	3
ND_4 PD_4	$P_6 + P_7 + ND_4 - PD_4 = 3850$	4
ND_5	$P_8 + P_9 + ND_5 - PD_5 = 2275$	5
ND_6	$P_{10} + P_{11} + ND_6 - PD_6 = 146$	6
ND_7	$P_{12} + ND_7 - PD_7 = 458$	7
ND_8	$P_{13} + ND_8 - PD_8 = 84$	8
ND_9 PD_9	$P_7 + ND_9 - PD_9 = 0$	9
ND_{10}	$P_9 - 0.5P_8 + ND_{10} - PD_{10} = 0$	10
ND_{11} PD_{11}	$P_{11} + ND_{11} - PD_{11} = 0$	11
PD_{12}	$P_6 + P_7 + P_8 + P_9 + P_{10} + P_{11} - 11P_{12} - 11P_{13} + ND_{11} - PD_{11} = 0$	12
ND_{13}	$3\,S_{13} - 2\,P_8 - 2\,P_9 - 2\,P_{10} - 2\,P_{11} - 2\,P_{13} + 3549 + ND_{13} - PD_{13} = 0;$	13
ND_{14}	$S_{13} + ND_{14} - PD_{14} = 17$	14
ND_{15}	$2S_{14} - 11P_6 - 11P_7 - 11P_8 - 11P_9 - 11P_{10} - 11P_{11} - 11P_{12} + 11P_{13} + 64474 + ND_{15} - PD_{15} = 0$	15
PD_{16}	$S_{14} + ND_{16} - PD_{16} = 2790$	16
ND_{17} PD_{17}	$20P_{20} - S_1 - S_2 - S_3 - S_4 + ND_{17} - PD_{17} = 0$	17
ND_{18}	$2P_{19} - 4S_1 - 4S_2 - 4S_3 - 4S_4 + ND_{18} - PD_{18} = 0$	18
ND_{19}	$2P_{19} - 6S_{10} - 6S_{11} - 6S_{12} + ND_{19} - PD_{19} = 0$	19
ND_{20} PD_{20}	$P_{21} + ND_{20} - PD_{20} = 6$	20
ND_{21}	$15P_{17} - S10 - S11 - S12 + ND_{21} - PD_{21} = 0$	21
ND_{22}	$P8 + P9 + P10 + P11 + P13 - 40S12 + ND_{22} - PD_{22} = 0$	22

ND_{23}	$21S_1 - S_2 - S_3 - S_7 + ND_{23} - PD_{23} = 0$	23
ND_{24}	$16S_2 - 3S_1 - 3S_3 - 3S_4 + ND_{24} - PD_{24} = 0$	24
ND_{25}	$3S_3 - 6S_1 - 6S_2 - 6S_4 + ND_{25} - PD_{25} = 0$	25
PD_{26}	$15S_4 - 5S_1 - 5S_2 - 5S_3 + ND_{26} - PD_{26} = 0$	26
ND_{27}	$13S_9 - 10S_1 - 10S_2 - 10S_3 - 10S_4 + ND_{27} - PD_{27} = 0$	27
ND_{28}	$P17 + ND_{28} - PD_{28} = 6$	28
ND_{29}	$P_{16} + ND_{29} - PD_{29} = 30$	29
PD_{30}	$S_9 + ND_{30} - PD_{30} = 278$	30
ND_{31}	$S_{10} + ND_{31} - PD_{31} = 10$	31
ND_{32}	$S_{11} + ND_{32} - PD_{32} = 12$	32
ND_{33}	$S_{12} + ND_{33} - PD_{33} = 50$	33
ND_{34} PD_{34}	$P_1 + ND_{34} - PD_{34} = 36$	34
ND_{35}	$P_{18} + ND_{35} - PD_{35} = 4$	35
ND_{36}	$900000P_7 + 2472695.03P_9 + 5000000P_{11} + 8850P_{14} + 700P_{15}$ $+17483051.45P_{16} + 6000000P_{18} + ND_{36} - PD_{36} = 2000000000$	36
ND_{37}	$S_{12} - 3S_{10} - 3S_{11} + ND_{37} - PD_{37} = 0$	37
ND_{38} PD_{38}	$S_{15} - 16P_6 - 16P_7 - 16P_8 + 16P_9 + 16P_{10} + 16P_{11} + 16P_{12} + 16P_{13} + 99589 + ND_{38} - PD_{38} = 0$	38
PD_{39}	$S_5 + S_6 + S_7 + S_8 + ND_{39} - PD_{39} = 0$	39
ND_{40}	$163840P_1 + 46252.23P_2 + 18432P_3 + 143360P_4$ $+ 2979.84P_5 + 39.56P_6 + 39.56P_7 + 189.76\ P_8$ $+ 189.76P_9 + 179.84P_{10} + 179.84P_{11} + 58.88P_{12}$ $+ 135.84P_{13} - 320S_1 + ND40 - PD40 = 0;$	40
ND_{41}	$163840P_1 + 46252.23P_2 + 18432P_3 + 143360P_4$ $+ 2979.84P_5 + 39.56P_6 + 39.56P_7 + 189.76\ P_8$ $+ 189.76P_9 + 179.84P_{10} + 179.84P_{11} + 58.88P_{12}$ $+ 135.84P_{13} - 384S_2 + ND41 - PD41 = 0;$	41
ND_{42}	$163840P_1 + 46252.23P_2 + 18432P_3 + 143360P_4$ $+ 39.56P_6 + 39.56P_7 + 189.76\ P_8$ $+ 189.76P_9 + 179.84P_{10} + 179.84P_{11} + 58.88P_{12}$ $- 448S_3 + ND42 - PD42 = 0;$	42

ND_{43}	$163840P_1 + 39.56P_6 + 39.56P_7$ - $512S_4$ + ND43 - PD43 = 0;	43
ND_{44} PD_{44}	$P_{14} - 1000P_{20} + ND_{44} - PD_{44} = 0$	44
ND_{45} PD_{45}	$P_{15} - 6000P_{21} + ND_{45} - PD_{45} = 0$	45
ND_{46}	$P_2 + ND_{46} - PD_{46} = 49$	46
PD_{47}	$P_3 + ND_{47} - PD_{47} = 9$	47
ND_{48}	$P_4 + ND_{48} - PD_{48} = 3$	48
PD_{49}	$P_5 + ND_{49} - PD_{49} = 8$	49

Mathematical representation	**Systematic constraints**
$\sum_{i=1}^{15}(\beta_i s_i) + \lambda_1 P_{14} + \lambda_2 P_{15} + \lambda_3 P_{18} + \omega_1 + \omega_2 \le 16647991600$	1
$\sum_{i=10}^{12}(\beta_i s_i) \le 600000000$	2
$p_6 + p_7 \ge 10p_1$	3
$p_8 + p_9 \ge 6p_2$	4
$p_{10} + p_{11} \ge 4p_3$	5
$p_{12} \ge 10p_4$	6
$p_{13} \ge 4p_5$	7

Entire Model

```
min = ND1 + ND2 + ND3 + ND4 + ND5 + ND6 + ND7 + ND8 + ND9
+ PD9 + ND10 + ND11 + PD11 + ND12 + ND13 + PD14 + ND15 +
PD16 + ND17 + ND18 + ND19 + ND20 + ND21 + ND22 + ND23 +
ND24 + ND25 + PD26 + ND27 + ND28 + ND29 + PD30 + ND31
+ ND32 + ND33 + ND34 + PD34 + ND35 + ND36 + ND37 + ND38
+ PD39 + ND40 + ND41 + ND42 + ND43 + ND44 + PD44 + ND45
+ PD45 + ND46 + PD47 + ND48 + PD49;
! SYSYEMATIC CONSTRAINTS;
28800000 * S1 + 26400000 * S2 + 22800000 * S3 + 13200000
* S4 + 28000 * S5 + 21000 * S6 + 15000 * S7 + 13000 * S8
+ 9000000 * S9 + 1625000 * S10
```

```
+ 2872354.14 * S11 + 8817500 * S12 + 600000 * S13 +
30000 * S14 + 12000 * S15 + 5370.69 * P14 + 600 * P15 +
4750000 * P18 + 304500000 + 777750000 < = 16647991600;
1625000 * S10 + 2872354.14 * S11 + 8817500 * S12 < =
600000000;
P6 + P7 > = 10 * P1;
P8 + P9 > = 6 * P2;
P10 + P11 > = 4 * P3;
P12 > = 10 * P4;
P13 > = 4 * P5;
!goal constraint;
37 * P2 - 50 * P1 + ND1 - PD1 = 0;
47 * P3 - 12 * P2 + ND2 - PD2 = 0;
2 * P5 - 8 * P4 + ND3 - PD3 = 0;
P6 + P7 + ND4 - PD4 =4000 ;
P8 + P9 + ND5 - PD5 = 2270;
P10 + P11 + ND6 - PD6 = 141;
P12 + ND7 - PD7 = 457;
P13 + ND8 - PD8 = 82;
P7 + ND9 -PD9 = 0;
P9 - 0.5 * P8 + ND10 - PD10 = 0;
P11 + ND11 - PD11 = 0;
P6 + P7 + P8 + P9 + P10 + P11 - 11 * P12 - 11 * P13 +
ND12 - PD12 = 0;
3 * S13 - 2 * P8 - 2 * P9 - 2 * P10 - 2 * P11 - 2 * P13
+ 3549 + ND13 - PD13 = 0;
S13 + ND14 - PD14 = 17;
2 * S14 - 11 * P6 - 11 * P7 - 11 * P8 - 11 * P9 - 11 *
P10 - 11 * P11 - 11 * P12 - 11 * P13 + 64474 + ND15 -
PD15 = 0;
S14 + ND16 - PD16 = 2780;
16 * P20 - S1 - S2 - S3 - S4 + ND17 - PD17 = 0;
2 * P19 - 4 * S1 - 4 * S2 - 4 * S3 - 4 * S4 + ND18 - PD18
= 0;
2 * P19 - 6 * S10 - 6 * S11 - 6 * S12 + ND19 - PD19 =0;
P21 + ND20 - PD20 = 7;
3* P17 - S10 - S11 - S12 + ND21 - PD21 = 0;
P8 + P9 + P10 + P11 + P13 - 50 * S12 + ND22 - PD22 = 0;
21 * S1 - S2 - S3 - S4 + ND23 - PD23 = 0;
16 * S2 - 3 * S1 - 3 * S3 - 3 * S4 + ND24 - PD24 = 0;
3 * S3 - 6 * S1 - 6 * S2 - 6 * S4 + ND25 - PD25 = 0;
15 * S4 - 5 * S1 - 5 * S2 - 5 * S3 + ND26 - PD26 = 0;
13 * S9 - 10 * S1 - 10 * S2 - 10 * S3 - 10 * S4 + ND27 -
PD27 = 0;
P17 + ND28 - PD28 = 22;
P16 + ND29 - PD29 = 30;
S9 + ND30 - PD30 = 278;
S10 + ND31 - PD31 = 10;
S11 + ND32 - PD32 = 15;
```

```
S12 + ND33 - PD33 = 50;
P1 + ND34 - PD34 = 36;
P18 + ND35 - PD35 = 4;
900000 * P7 + 2472695.03 * P9 + 5000000 * P11 + 8850 *
P14 + 700 * P15 + 17483051.45 * P16 + 6000000 * P18 +
ND36 - PD36 = 2000000000;
S12 - 3 * S10 - 3 * S11 + ND37 - PD37 = 0;
S15 - 17 * P6 -17 * P7 - 17 * P8 - 17 * P9 - 17 * P10 -
17 * P11 - 17 * P12 - 17 * P13 + 99589 + ND38 - PD38 = 0;
S5 + S6 + S7 + S8 + ND39 - PD39 = 4500;
163840 * P1 + 46252.23 * P2 + 18432 * P3 + 143360 * P4 +
2979.84 * P5 + 39.56 * P6 + 39.56 * P7 + 189.76 * P8 +
189.76 * P9 + 179.84 * P10 + 179.84 * P11 + 58.88 * P12
+ 135.84 * P13 - 320 * S1 + ND40 - PD40 = 0;
163840 * P1 + 46252.23 * P2 + 18432 * P3 + 143360 * P4 +
2979.84 * P5 + 39.56 * P6 + 39.56 * P7 + 189.76 * P8 +
189.76 * P9 + 179.84 * P10 + 179.84 * P11 + 58.88 * P12
+ 135.84 * P13 - 384 * S2 + ND41 - PD41 = 0;
163840 * P1 + 46252.23 * P2 + 18432 * P3 + 143360 * P4 +
39.56 * P6 + 39.56 * P7 + 189.76 * P8 + 189.76 * P9 +
179.84 * P10 + 179.84 * P11 + 58.88 * P12 - 448 * S3 +
ND42 - PD42 = 0;
163840 * P1 + 39.56 * P6 + 39.56 * P7 - 512 * S4 + ND43 -
PD43 = 0;
P14 - 1000 * P20 + ND44 - PD44 = 0;
P15 - 6000 * P21 + ND45 - PD45 = 0;
P2 + ND46 - PD46 = 49;
P3 + ND47 - PD47 = 9;
P4 + ND48 - PD48 = 2;
P5 + ND49 - PD49 = 8;
@GIN(S1);@GIN(S2);@GIN(S3);@GIN(S4);@GIN(S9);@GIN(S10);@
GIN(S11);@GIN(S12);@GIN(S13);@GIN(S15);
     @GIN(P2);@GIN(P3);@GIN(P4);@GIN(P5);@GIN(P6);@GIN(P
     7);@GIN(P8);@GIN(P12);@GIN(P13);@GIN(P20);
```