On Multiple Criteria Financial Resource Allocation at Higher Education Institutions

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ABSTRACT

The increasing competition among higher education organisations, along with financial support from government that is gradually reduced on one hand and the increasing expenditure of higher education on the other hand, has caused any higher education institutions to allocate their financial resources to their units appropriately. This paper is about financial resource allocation in higher education which is addressed with multiple criteria as their bases. At the end of the paper, a numerical example of financial resource allocation planning outperformed by a higher education institution, of which criteria are performance and its needs, is presented.

Keywords: financial resource allocation, multiple criteria, higher education institutions

1. Introduction

The internationalisation of higher education has caused the increasing competition among them. On the other hand, the highly level of the competition has also given every organisation needs to give more attention on productivity improvement issues (including here is higher education organisation), as it was inferred that high productivity is one of key success factor in order to be the winner in certain competition ([1], Drucker, 1991, in [2], Grossman, 1993, in [3]). In the UK, for instance, a simultaneously increasing pressure on resource utilization – and pressures from a range of stakeholders - led the higher education sector "... the challenges of reorienting their approaches to be more customer-focused and conducting their activities in a more business-like manner" [4].

In line with budget constraints ([5], [6], [7]), the increasing expenditure of higher education organisation itself [6], the complexity of social problems that is in progress which, in turn, insists government to switch its priority from higher education to those social problems [6], and the needs of accountability in managing funds of higher education [6], it is inferred that the need of productivity improvement has raised the need of resource allocation, including financial, more appropriately and wisely ([6], [7], [8], [9]). Financial resource allocation or, as other

literature name it, capital budgeting, attracts more interests from both practitioners and academics as "... capital investments are an important part of the process whereby a firm creates value and can thus have significant implications for the company's competitive position" [10].

In term of managing higher education resources, those resources owned by a higher education organisation comprises a broad range of things [11], including students, lecturers, staffs, facilities, equipments, external supports (e.g. government, society, and business community), fund, and time. Resource allocation itself is concerned with the determination of level of certain resources that have to be allocated to a series of activities which need those resources [11].

2. Literature review and previous related researches

2.1 Resource allocation in the organisations of higher education

Studies on resource allocation in higher education institutions could be traced back to 1976, within which Dufty published his paper "Some notes on resource allocation in Tertiary institutions" in *The Journal Of Educational Administration* Vol. XIV No. 2 [12]. In 2004, Spathis and Ananiadis [13] issued their paper "The accounting system and resource allocation reform in a public university" in

The *International Journal of Educational Management* Volume 18 Number 3, of which main content was the accounting system reform practised in Greek universities since January 2000. On the other hand, Shaw [14] proposed risk adjusted performance measures (RAPM) as "… a single statistic to be used to evaluate past/future performance and allocate scarce capital resources based on expected future performance …".

2.2 Multiple criteria decision making

Real world problems sometimes involve multiple objectives or, in another word, performance measures of almost all of systems in real world are a set of performance measures [15]. Decision-making "involves the evaluation of alternative courses of action within which the decision-maker evaluates various alternatives based on a set of preferences, criteria, and objectives …" [16].

Sometimes those objectives, in nature, conflict to each other [17]. In broader scope, especially in real-world contexts, "decisions are often made in the presence of multiple, usually conflicting and incommensurate criteria or attributes" [18]. In more specific context, many significant business decisions which have to be made by managers or other decision-makers consist a serial of selection processes from a limited number of alternatives on one hand and, on the other hand, trying to satisfy multiple objectives that conflict to each other [19]. Due to these, it is frequently a high level of difficulty in choosing between possible courses of action as it requires a balance among several factors. Multiple criteria decision making (MCDM) deals with such situations [20]. In such problems, there are generally no perfect alternative, and a good compromise must be identified [21].

There are lots of literatures on MCDM, some of it will be subsequently mentioned. In transportation sector, Shang *et al.* [22] stated the following, "…the need to account for social, technical, political, economic, and environmental factors and the like makes the transportation projects evaluation field well suited to multi-criteria decision-making (MCDM)". The use of compromise programming - an MODM approach - in flexible manufacturing systems model with multiple objectives was proposed by Park *et al.* [23]. Baykasoglu [24] applied multiple-objective tabu search in planning aggregate production. Dimova *et al.* [25] proposed an MCDM method in assessing investment

projects in a fuzzy setting. Tarp and Helles [20] presented an overview of MCDM application in the context of forest management planning. In selecting suppliers, Kahraman *et al.* [26] proposed AHP method combined with fuzzy thinking, while Çebi and Bayraktar [27] applied AHP in combination with lexicographic goal programming (LGP) method. Liao and Rittscher [28], on the other hand, presented a multi-objective supplier selection model in stochastic demand conditions context. The usage of fuzzy mixed integer goal programming (f-MIGP) in vendor selection problem (VSP) was proposed by Kumar *et al.* [29]. Parkan and Wu [30] provided the use of and compares some of the current multi-attribute decision-making (MADM) and performance measurement methods through a robots selection problem. In its Volume 37 (1999), the journal of *Computers & Industrial Engineering* presented specific papers on MCDM.

In broader sense, methods for supporting MCDM could be categorized as multiple objective decision making (MODM) approach and multiple attribute decision making (MADM) one. In MODM the alternatives are often defined implicitly, e.g., by the restrictions of a mathematical program. In MADM problems, on the other hand, the decision maker must choose from a set of alternatives that is typically defined explicitly [21]. One method of MADM approach is AHP, which is "… widely used for multi-criteria decision making and has successfully been applied to many practical decision-making problems" (Saaty, 1988, in [31]). Eigenvector method, ELECTRE, and TOPSIS are other examples of MADM techniques [32].

2.3 Multi-criteria financial resource allocation in higher education institutions

In general, academic resource allocation can be conducted by adopting approaches used by GEF Council [33]: (i) based on organisational performance at one side, and (ii) based on the needs of resource at another side.

One of academic resources having to be allocated appropriately are financial resources. Practically, bases that are used in financial resource allocation vary among higher education organisations, one of them is by utilising combination of various performance measures. It was chosen as using one performance measure may not reflect the fact accurately [34]. Additionally, the usage of

many performance measures is in order to deploy financial resources to every people in the organisation [34].

It was issued by Al-Turki and Duffuaa [35] that performance measures must be based on a set of objectives that are linked to the mission of the department [or organisation in general] and its vision for the future.

Performance of a higher education can be measured from various aspects, one of them is by using its input and output elements [36]. Input elements can be student amount, while output elements can be the amount of graduates, research publications, and the amount of doctoral theses [36]. Hanoum's research [37] and Setiawan's research [38] used ratio of lecturer with bachelor qualification and master and doctoral qualification, ratio of subjects and lecturers, and the amount of students per laboratory as input measures, while output measures are taken from *Tri Dharma Perguruan Tinggi* (education, research, and community service).

3. A numerical example (depicted from [39])

Higher Education "X" (HEX) which is located in Surabaya also faces problems mentioned in "Introduction" section. In accordance with many factors explained in previous paragraphs, the fact of the increasing expenditures in conducting education on one side, and the decreasing financial support from government [37], the needs of performance, quality, and productivity improvement in HEX are mandatory.

Productivity of educational process in HEX is very closely related with its resource allocation (including financial resource) to its sub-organisations appropriately, in such a way that these resources can be used efficiently at one side and also giving supports to the effectiveness of educational process at the other side. Those high efficiency and effectiveness will result in high productivity, because productivity improvement are closely related to input/ output ratio [8].

Financial resource allocation in HEX has to be conducted to all of its sub-organisations without exception, including department. The allocation to department should be highly prioritised, as they are directly related to the operation of educational process. This makes them absorb a large portion of financial resources owned by HEX.

This research was aimed at identifying the optimum level of allocation of DIK-S 2003/ 2004 HEX to its various departmental units based on performance (with certain measure) and needs of department. To did this, some constraints below were considered:

a. The levels of productivity used were based on Hanoum's research [37] together with the calculation of the productivity level at other periods conducted by Setiawan [38]

b. The allocation process was concerned with the budget period 2003/ 2004

The assumptions made were as follows:

a. Secondary data were assumed valid

b. Paradigm used in allocating financial resource was based on Aristotle's equity principle, which stated that goods should be divided in proportion to each claimant's contribution to the common sense (Young, 1994 in [40], [13]). In this paper, the financial resources were considered to be allocated proporsionally according to productivity (as performance measure) achieved by each departmental units in the past

c. The respondents involved in this research were assumed having competences in giving their opinions

3.1 Mathematical model building

Mathematical model used in this resource allocation was a modification of model used in Setiawan [38], and formulated as follows:

$$\text{Min } z = w_1\left(d_t^- + d_t^+\right) + w_2\left(\sum_j d_j^- + \sum_j d_j^+\right) \quad (1)$$

Subject to:

$$\sum_{j=1}^{n} PB_j x_j + d_t^- - d_t^+ = TB \quad (2)$$

$$PB_j x_j + d_j^- - d_j^+ = b_j$$

where:

w_1 : Weight of goal 1

w_2 : Weight of goal 2

d_j^- : Under-budget of allocation to department j

d_j^+ : Over-budget of allocation to department j

d_t^- : Under-budget of total financial allocated

d_t^+ : Over-budget of total financial allocated

b_j : (student ratio of department j x estimate of total financial) x (multiplier factor of department j)

TB : Plan of total financial allocated

to all departments involved in the model

PB$_j$: Plan of financial allocation to department j

x_j : Optimum percentage of optimum financial planned to be allocated to department j

Data envelopment analysis (DEA) model used was output-oriented DEA, and formulated as follows ([37], [38]):

Objective Function:

$$\text{maximize}: \theta_k + \varepsilon \left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \right]$$

$$\text{subject to}: \quad 0 = \theta_k y_{rk} - \sum_{j=1}^{n} y_{rj} \lambda_j + s_r^+ \tag{3}$$

$$x_{ik} = \sum_{j=1}^{n} x_{ij} \lambda_j + s_i^-$$

$$0 \le \lambda_j, s_i^-, s_r^+$$

for $i = 1,..., 4; r = 1,..., 5; j = 1,..., 17$

θ_k unrestricted in sign

Constraint Functions:

a. Output 1: the amount of graduates

$$\sum_{j=1}^{17} y_{1j} \lambda_j - \theta_k y_{1k} - s_1^+ = 0 \tag{4}$$

b. Output 2: graduate's skill

$$\sum_{j=1}^{17} y_{2j} \lambda_j - \theta_k y_{2k} - s_2^+ = 0 \tag{5}$$

c. Output 3: lenght of study

$$\sum_{j=1}^{17} y_{3j} \lambda_j - \theta_k y_{3k} - s_3^+ = 0 \tag{6}$$

d. Output 4: number of researches

$$\sum_{j=1}^{17} y_{4j} \lambda_j - \theta_k y_{4k} - s_4^+ = 0 \tag{7}$$

e. Output 5: number of social services

$$\sum_{j=1}^{17} y_{5j} \lambda_j - \theta_k y_{5k} - s_5^+ = 0 \tag{8}$$

f. Input 1: lecturer quality

$$\sum_{j=1}^{17} x_{1j} \lambda_j - x_{1k} + s_1^- = 0 \tag{9}$$

g. Input 2: lecturer specialization

$$\sum_{j=1}^{17} x_{2j} \lambda_j - x_{2k} + s_2^- = 0 \tag{10}$$

h. Input 3: size of classes

$$\sum_{j=1}^{17} x_{3j} \lambda_j - x_{3k} + s_3^- = 0 \tag{11}$$

i. Input 4: facility

$$\sum_{j=1}^{17} x_{4j} \lambda_j - x_{4k} + s_4^- = 0 \tag{12}$$

$$\lambda_j, s_r^+, s_i^-, \varepsilon \ge 0$$

Indexes:

j = DMU = 1, 2, ..., 17;
r = output = 1,...,5;
i = input, $i = 1,..., 4$

Data:

y_{rj} = r^{th} output values of DMU j
x_{ij} = i^{th} input values of DMU j
ε = small positive number (10^{-6})
y_{ro}, x_{io} = output and input values of DMU being observed

Variables:

θ_k = relative efficiency of DMU$_k$
s_r^+, s_i^- = slack from input i, output r ($s_r^+, s_i^- \ge 0$)
λ_j = weight of DMU j relative to DMU being evaluated

3.2 Data collection and data sources

Data which were collected in this research consisted of two sorts of data, primary and secondary. Secondary data included the following:

a. Productivity indicator of various department in HEX 1998 – 2001, obtained from Hanoum [37]

b. Productivity level of various departments in HEX 1998 – 2001, obtained from Hanoum [37]

c. Variable values of various departments in HEX, involved:
1. Average lengths of study;
2. Number of regular graduates;
3. Number of regular undergraduate students;
4. GPA;
5. Number of lecturers;
6. The amount of researches conducted by lecturers;
7. The amount of social services conducted by lecturers;
8. Number of laboratory;
9. Number of subjects offered per semester;

4

Those data were obtained from various sub-organisation in HEX, such as *Biro Administrasi Perencanaan dan Sistem Informasi* (BAPSI), *Biro Administrasi Akademik dan Kemahasiswaan* (BAAK), *Biro Administrasi Umum dan Keuangan* (BAUK), and *Lembaga Penelitian dan Pengabdian Masyarakat* (LPPM).

d. Plan of financial resource allocation to various departments, obtained from *Petunjuk Operasional Penggunaan Dana Penerimaan Negara Bukan Pajak* (PNBP) year 2003-2004.

e. The amount of students of HEX in academic year 2003/2004, obtained from BAAK HEX.

Primary data were respondents' opinions on the weight of goals involved in this research, and were obtained by the following steps:

a. First step was determining fuzzy preference relation values of each individual involved in this research

b. Second, those individual assessments were aggregated to gain group assessment. The method implemented was ordered weighted averaging (OWA)

c. Finally, weighting was carried out

3.3 Data processing

Data processing was conducted by applying several methods. Productivity values were obtained by applying an output-oriented DEA approach assisted by LINDO version 6.01. These values were then projected to year 2003/ 2004 and represented the estimates of productivity values of each department in year 2003/ 2004. The weights of goals were determined by using fuzzy preference relation and ordered weighted averaging (OWA). The calculation was outperformed by applying Excel. Finally, the allocation process of DIK-S 2003/ 2004 was conducted by applying goal programming and fuzzy goal programming, assisted by LINDO version 6.01.

3.4 Results

3.4.1 Estimates of productivity values in academic year 2003/ 2004

The estimates of productivity values of various departments in year 2003/ 2004 were presented in Table 1 below, together with multiplier factor.

Tabel 1. Estimates of productivity values and multiplier factor for each department

DMU	Deparments	The estimates of productivity values	Multiplier factor	DMU	Deparments	The estimates of productivity values	Multiplier factor
1	Pysics	1,00	1,167	10	Civil Eng.	1,00	1,164
2	Mathematics	1,00	1,167	11	Architecture	0,94	1,098
3	Statistics	1,00	1,167	12	Environmental Eng.	0,97	1,128
4	Chemistry	1,00	1,167	13	Industrial Product Design	0,59	0,690
5	Mechanical Eng.	0,87	1,018	14	Naval Eng.	0,70	0,812
6	Electrical Eng.	0,76	0,886	15	Naval Systems Eng.	0,89	1,042
7	Chemical Eng.	0,88	1,023	16	Marine Eng.	0,95	1,103
8	Eng. Physics	0,79	0,922	17	Informatics	0,57	0,668
9	Industrial Eng.	0,87	1,010				

Multiplier factor was calculated as follows:

1. First, the estimates of productivity values were summed.

2. This sum was used as denominator of each of the productivity value estimate of each department, yielding multiplier factor.

From Table 1 it could be stated that several departments had maximum productivities relative to their peers. Those departments were Physics, Mathematics, Statistics, Chemistry, and Civil Engineering. Among the others, Informatics had least productivity value. It should be noted,

however, those values were estimates based on the past values. It can be criticised, then, how those values were determined. In this case, they were averages of three periods of time in the past. If the periods of time were extended and involved more periods, the estimate values of department productivity could be expected significantly different, leading to different conclusion.

3.4.2 b_j values of each department

By following formula involved as part of mathematical model developed at section 3, b_j values of each department were resulted and

being presented in Table 2 below.

Table 2. b_j values of each department

DMU	Departments	b_j values	DMU	Departments	b_j values
1	Physics	471,091,482.92	10	Civil Engineering	1,266,236,279.85
2	Mathematics	804,526,363.70	11	Architecture	659,100,282.94
3	Statistics	648,515,547.92	12	Environment Engineering	770,247,864.48
4	Chemistry	497,093,285.55	13	Industrial Product Design	536,274,891.96
5	Mechanical Engineering	1,519,690,617.06	14	Naval Engineering	544,891,044.52
6	Electrical Engineering	1,625,718,835.67	15	Naval System Engineering	729,277,233.39
7	Chemical Engineering	1,194,639,905.42	16	Marine Engineering	425,017,216.60
8	Engineering Physics	755,256,755.13	17	Informatics	613,731,141.36
9	Industrial Engineering	833,960,734.55			

3.4.3 The weight of goal

The weight of goal, that were based on respondents' opinions processed by fuzzy preference relation and ordered weighted averaging, were 0.717 for goal *financial resource allocation that is based on needs*, and 0.283 for goal *financial resource allocation that is based on performance of each department (presented by its productivity value)*. By realising the fact that fuzzy quantifier used in fuzzy preference relation was *most*, it was able to be stated that most of respondents proposed that the optimum allocation of DIK-S 2003/ 2004 was better based on needs instead of on performance.

Looking at their opinions more deeply, there were several respondents that gave scores 1 in weighting the goal. It meant that, for them, goal *financial resource allocation based on need* was absolutely more important compared with goal *financial resource allocation based on performance*. In other words, those respondents supposed that the only best way in allocating financial resource was by considering needs of department units.

3.4.4 Optimum values of financial resource allocation planning

The optimum values of proposed financial resource allocation, together with x_j values and original values of financial resource allocation, were presented in Table 3.

Tabel 3. Proposed financial resource allocation, x_j values, and original financial resource allocation to each department

No.	Departments	x_j values	Financial resource allocation	
			Original (Rp)	Proposed (Rp)
1.	Physics	3,360299	140,193,341.00	471,091,544.00
2.	Mathematics	1,622063	495,989,698.00	804,526,538.00
3.	Statistics	1,672959	387,645,735.00	648,515,421.00
4.	Chemistry	3,256557	152,643,787.00	497,093,193.00
5.	Mechanical Engineering	0,859415	1,934,680,400.00	1,662,693,356.00
6.	Electrical Engineering	0,608034	2,673,730,208.00	1,625,718,873.00
7.	Chemical Engineering	0,788811	1,514,482,261.00	1,194,640,267.00
8.	Engineering Physics	1,241399	608,391,877.00	755,257,068.00
9.	Industrial Engineering	0,768697	1,084,901,857.00	833,960,803.00
10.	Civil Engineering	0,978777	1,293,692,425.00	1,266,236,391.00
11.	Architecture	1,616990	407,509,376.00	659,100,285.00
12.	Environment Engineering	1,009700	762,848,000.00	770,247,526.00
13.	Industrial Product Design	0,628531	853,220,000.00	536,275,220.00
14.	Naval Engineering	1,539615	353,913,757.00	544,890,929.00
15.	Naval System Engineering	1,223225	596,192,005.00	729,276,965.00
16.	Marine Engineering	3,397719	125,088,997.00	425,017,262.00
17.	Informatics	0,939792	653,049,775.00	613,730,954.00
18.	Total		14,038,273,499.60	14,038,272,693.00

From Table 3 above, there were three profiles:

1. Departments with original values of financial resource allocation > proposed values of financial resource allocation

   Included in this profile were Mechanical Engineering, Electrical Engineering, Chemical Engineering, Industrial Engineering, and Industrial Product Design

2. Departments with original values of financial resource allocation < proposed values of financial resource allocation

   Included in this category were Physics, Mathematics, Statistics, Chemistry, Engineering Physics, Architecture, Naval Engineering, Naval Systems Engineering, and Marine Engineering.

3. Departments with original values of financial resource allocation ≈ proposed values of financial resource allocation

   This profile included Civil Engineering, Environment Engineering, and Informatics.

Those conditions were attributed to the fact that there were not permanent parallelism between the total amount of financial resources planned to be allocated and the productivity values of each department. In addition, optimisation processes which were based on *goal 2* involved proportional allocations that were determined by including student bodies. The latter contributed to the differences between original allocation plans and allocation plans proposed by Setiawan {38}.

Meanwhile, productivity values induced were average values of three last semesters, and several departments having high productivity levels at earlier periods had also been affected, resulting in a declining productivity levels.

On the opposites were several departments with higher financial allocations than the original ones, and these conditions were related with their high productivity values. Engineering Physics and Naval Engineering had student amount that were relatively high. These made them being proposed to be allocated higher financial resource in contrast with the original schemes.

3.5 Research limitations and suggestions for future work

This research was conducted by asking several individuals that were supposed to be having competency to give his/ her opinions. They were samples from much larger population, however, and not all of individuals supposed to be having competences and authorities being involved. Therefore it was sugested to undertake similar research with broader scope of respondents involved.

One of the methods used was data envelopment analysis which, regarding its nature and characteristics, made departmental units involved were limited. It was sugested, then, to utilise other methods to similar research

theme in such a way that other departments with different characteristics could be included.

This research was about DIK-S HEX 2003/ 2004. It was recommended, then, to broaden the scope of financial resources involved in future research.

Finally, in order to give much more benefit, the generalisation of the result should be improved. It was highly recommended, then, to develop a decision support system.

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