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Optimal budget allocation for university research and publication agenda through integer programming

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ABSTRACT

For the past few years, government-funded universities in Malaysia faced an uphill battle to strategize their management budget due to significant budget cut by the Malaysian Government. One portion of the budget will be spent towards achieving the key performance indicators (KPIs) set by the universities to achieve their annual targets. Unfortunately, some universities set up their specific strategies to achieve the KPIs without ample consideration to the limited available resources where less attention is channeled to the cost of achieving the KPIs. Setting priorities and making decisions on allocation and reallocation of resources based on the direction of the strategies must be executed with transparency and accountability and will be of great importance. In this paper we illustrate how integer programming was applied to allocate budget based on the KPIs set for one of the government-funded Malaysian universities' (U-XYZ's) research and publication agenda. Two models were developed and successfully solved. The first model was to determine the total budget needed if all the KPIs were to be achieved while the second model was to distribute the allocated budget set by U-XYZ, for all the activities planned for the agenda. The result showed that in order to achieve the target, U-XYZ has to increase its budget allocation by RM2.164 million. Otherwise, U-XYZ can only expect to obtain 1.578 out of 1.593 points that is required to be achieved.

1. Introduction

One popular measure used by universities to improve the performance of the institutions is through a proper strategic plan. A strategic plan designed by different universities is used as a guide and key indicator of progress in assessing the universities and equipping the universities with challenges and realities of the educational needs in this millennium [1]. Normally a university strategic plan consists of several main thrusts such as student development, staff development, internationalization of activities, wealth generation, and research and publication [2]. Under each

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thrust there will be a list of agendas and key performance indicators (KPIs). The KPIs are normally set to achieve many objectives: one of the objectives is university ranking [3-4].

Universities rankings are increasingly popular. Today, more than 33 countries have some forms of ranking system operated by government and accreditation agencies, higher education, research and commercial organisations, or the media. Among the more popular ones are the Shanghai Jiao Tong Academic Ranking of World Universities and the Times QS World University Ranking. Universities strive to be ranked to support their reputation and status, thus making their marketing tasks easier [4]. The ranking mechanism is normally based on a few criteria. One of the more prominent criteria is research and publication [3, 5].

In recent years, the financial crisis has reduced the overall government spending, thus reducing the budget allocation for research centres as well as government-funded universities [5-7]. To face these challenges, research institutions need to consciously manage their core processes, the creation and development of their knowledge assets [8-10], and consistently redesign their support processes and managerial instruments [9-11].

This current global financial crisis has also impacted Malaysian government-funded universities. The fund has been reduced by the government since as early as 2010 and in 2017, the fund has continued to be cut even further. The budget for 20 government-funded universities' combined-operating expenditure in 2017 is RM6.12 billion, which is a cut of RM1.46 billion or 19.23 per cent from the allocation of RM7.57 billion in 2016 [3, 8].

With the severe budget cut, these universities, in order to attain financial sustainability, has to look for other alternatives to fund their research and publication activities such as institutional funding, scientific chairs in specific subjects, local and international endowments, organizational and private sector partnership funding, and return on investment in research [14,16]. Failing to secure such grants will result in reduced number of research activities and publications and therefore, affecting the ranking of the universities as well.

2. Problem Statement and Research Objective

At one of the Malaysian government-funded universities (later to be referred to as U-XYZ), the research and publication agenda is one of the main thrusts in its (i.e. U-XVZ's) strategic plan. Basically, the process of developing the U-XYZ strategic plan is as follows:

Step 1: The top management decides on the main thrusts through a series of workshops.

Step 2: The faculty deans and other management team members elaborate on the specific agenda and strategy along with the KPIs under each main thrust.

Step 3: The strategic planning office distributes the finalised strategies and KPIs to the respective schools and research units.

Step 4: The treasurer's office allocates the budget to each school and research unit.

Step 5: Each school and research unit plans and executes suitable activities to achieve the KPIs given.

Since the allocation of budget is done separately and only after the strategies and the KPIs are set, schools and research units face several difficulties in managing the amount allocated. The school deans and the research unit directors do not really know how to properly distribute the amount and to prioritize the activities (i.e. research versus publications). Thus, there is a need for a mechanism to tackle this problem.

The objective of this study was therefore to help alleviate this problem by developing a mathematical model for the U-XYZ research and publication agenda that can:

i. Prioritize the activities under the agenda based on certain objectives.

ii. Distribute the budget allocated based on certain criteria.

iii. Determine the minimum amount of budget required to fulfil all the KPIs set.

3. Literature Review

Setting priorities and making decisions on allocation of budget for activities based on the direction of the KPIs must be executed with transparency and accountability and will be of great importance. A good budgeting process is one that provides information and focuses on outcomes [38], and its success must be measured to the extent to which it can provide necessary motivation for individuals or organizations in order to maximize their contribution in achieving the organizational goals [39]. Therefore, the review of existing techniques to evaluate the cost-effectiveness of a strategy or activity that gives maximum benefit towards the achievement of the KPIs set is therefore needed. At the same time a suitable mathematical model that can assist the budget allocation process should also be determined. One way of measuring cost effectiveness is through marginal contribution [37] and one suitable mathematical model to be used for budget allocation is integer programming model [24-27].

3.1 Marginal Contribution

When allocating and re-allocating funds, organizations require evidence of effectiveness of interventions with reasonable value for money [9]. As such, economic evaluators are needed for public funded services to perform a comparative analysis or alternative of actions particularly with regards to consequences and cost in executing or implementing certain options. Increase emphasis on economic evaluators to interventions for improving organizational strategies in institutions as well as other organizations in an environment that is the process of being cost-effective requires assessment of different interventions about its economic implication [12]. Furthermore, cost-effective analysis can help identify opportunities that are often neglected as well as ways to redirect resources to achieve more [32]. Failure to evaluate the cost effectiveness may lead to over expenditure or reduced services when improvements are actually possible with less expenses through the process of cost effectiveness.

Depending on the type of the analysis of the consequences, there are mainly five economic evaluators that can be used. They are cost-effectiveness analysis (CEA), cost-benefit analysis (CBA), cost-utility analysis (CUA), cost-minimization analysis (CMA), and cost-consequences analysis (CCA) [12].

3.1.1 Cost-effectiveness analysis (CEA)

CEA is used as a method of assessing services that are less costly with maximum benefit and also as priority settings aimed at benefiting services, and making decisions for any organizations [13-14]. CEA is calculated as the amount of cost per unit effect. The basic requirement of CEA is a fixed budget constraint and used when there is a single objective for an intervention [15]. The major advantage of CEA is the result or outcome can be compared with results of other technologies that are expressed using the same outcome measures [12]. It is straightforward to conduct than most of its competitors like CUA or CBA. Nevertheless it is not suitable for comparing technologies and allocation of resources across different conditions because of its reliance on one common measure.

3.1.2 Cost-benefit analysis (CBA)

CBA is a direct economic evaluation to address allocation efficiency, and values the cost and results of an economic evaluation in monetary terms [16]. The most widely CBA-values used by economic evaluators are monetary values determined for intervention of input and output. It has a single unit measurement for various outcomes and also allows for comparison between different multiple outcomes such as comparison of social and financial CBA. CBA primarily is used to evaluate the consequence of an intervention using performance of a certain measure when the attribute of an intervention on performance of that measure and the outcome process is considered an important factor in analysing the various responses. The major disadvantage of CBA is uncertainty in assigning and quantifying of monetary value to alternatives which can be a major cause of inaccuracy in analysis of cost-benefit. In addition, not all alternatives can be quantified and estimated using monetary measures. Inaccuracy in the calculation of the present value as evaluations made on the pass period of time, with decision on the present and future will surely be not realistic. It requires the benefit and cost to be identified and qualified appropriately. Furthermore, the imperfection in human gives rise to omission and also errors when doing the CBA [17-18].

3.1.3 Cost-utility analysis (CUA)

CUA, regarded as a special case of CEA, estimates the ratio between cost and benefit of intervention to an individual. It is used by policy makers to determine priorities when choosing alternatives for the individual [19]. As a special case of CEA, CUA deals with individuals and not group and allows comparison between alternatives with complete analysis of total benefit compared to other economic evaluators. However, one of the disadvantages of CUA is the social benefits and cost are not considered. Rather, individual benefits are mostly considered.

3.1.4 Cost-minimization analysis (CMA)

CMA regards factors that are relevant to the decision, considering equivalent and the lowest cost options selected. Normally applied as an extension of CEA, outcomes will be demonstrated as equivalent to CEA by comparing benefits yielded by different methods/processes on the same treatment only by cost [12].

3.1.5 Cost-consequence analysis (CCA)

CCA is used to assess the impact of interventions, the cost and outcomes of alternative interventions, listed separately, in a disaggregated format. The outcome is disaggregated for the purpose of showing the trends, insight, and patterns that cannot be applied in an aggregated data set. The transparency of CEA, CBA, CMA, is improved with CCA as an intermediate step in reporting the analysis showing outcome and cost presented in disaggregation before it is combined for other economic evaluations ([20], [12]). CCA compares interventions across different sectors and report in different, disaggregated format. According to Golan, Hansen, Kaplan, and Tal in [21], process of economic evaluation accepts the fact that different types of benefit cannot be compared using the same unit, hence CCA is a very useful technique that allows for multiple outcomes, with different perspectives and units.

All of the analyses above can be applied in various fields or organizations, with some modification, if required, to weigh alternatives and to make decisions based on the best alternatives surrounding cost-minimization and benefit-maximization. The determination of the best set of alternatives to be selected can be done using some mathematical programming models. One of the models is integer programming model [33-34].

3.2 Integer Programming Model

Integer programming (IP) is a mathematical technique applied in fields of mathematics, computer for modeling as well as simulations to find the best possible solution in strategic planning [24], routing [25], scheduling ([26,30], assigning [27-29], and allocation of limited resources [31] to achieve maximum benefit with minimum cost. In planning and resource allocation, IP is used for priority setting to determine the set of activities, projects or strategies to be implemented based on limited budget allocated in order to maximize or minimize the intended objective [22]. IP is a subset of linear programming.

The general IP-model for planning and resource allocation may appear as follows [23]:

Maximize/Minimize $f(x)=\sum_{j=1}^{n} c_j x_j$ as the objective function,

Subject to a set of constraints

$$\sum_{j=1}^{n} a_{ij} x_j = b_i, \quad i=1,\dots,m \qquad (1)$$
$$x_j \geq 0 \; and \; \text{int}$$

where all the right-hand-side parameters b_i are nonnegative. The equality '=' sign can also be replaced with a combination of '=', '≥' and/or '≤'. Some of suitable objectives used in previous studies involving resource allocation or budget allocation are to minimize the budget to be allocated [40], to maximize the efficiency of the allocated budget utilization [41], or to maximize the total net social profit on its output to society [42].

One good feature of IP is in its ability to allow users to do post-optimality and sensitivity analysis by looking at the effects of changes in the model parameters (both in the objective function and constraints) on the current optimal solution [35].

4. Methodology

This section of the paper illustrates the steps performed for this study. All together the process involved four step. Data were extracted from The 2016 Strategic Plan of U-XYZ, and they were:

i. The strategies planned by U-XYZ to achieve the research publication and citation.
ii. The expected rating point to be accumulated.
iii. The expected number of products to be produced to achieve the targeted rating point.

Due to confidentiality issue, the amount of money required to achieve each product was not furnished by the treasurer's office. Therefore, a hypothetical amount was used for each product.

STEP 1: Identify the KPIs

The first step is the identification of the specific KPIs (in the form of strategies) to improve the U-XYZ research and publication agenda. From the U-XYZ strategic plan, five different strategies were documented to increase U-XYZ research and publication. The strategies are:

A. Number of staff with PhD.

B. Number of journal publications (indexed by Scopus).
C. Number of journal publications (other than Scopus).
D. Number of postgraduate students inbound.
E. Number of postgraduate students outbound.

STEP 2: Calculate the marginal contribution

We applied CCA to determine the marginal contribution of each output from strategy towards the achievement of the U-XYZ research and publication agenda where

$$\text{CCA} = (\text{Total expected rating point}) / (\text{Total output needed to achieve full point}) \quad (2)$$

The CCA-value, the amount of money (RM) required to achieve each output *i* and total point needed for strategy *i* are given in Table 1.

Table 1
CCA-value, amount required per output *i* and total point needed for strategy *i.*

Strategy *i*	Rating points to be achieved	Total output required (KPI)	CCA	Total amount (RM) required per output
A	0.75 for 900 staff 0.0828 for 66 staff	U-XYZ needs to achieve 75% out of 1200 academic staff, i.e. 900 staff. However, at the point this study was conducted, U-XYZ already had 834 staff with PhD. Thus, U-XYZ only needs additional 66 staff. 66	0.75/900 = 0.0008	125,000
B	0.75	1200	0.000625	1000
C	0.75	1200	0.000625	500
D	0.02	U-XYZ needs 2% out of 3000 students, i.e. 60 students. 60	0.000333	2000
E	0.02	U-XYZ needs 2% out of 3000 students, i.e. 60 students. 60	0.000333	100

STEP 3: Develop and solve the IP model

Two IP models, i.e. Model A and Model B were constructed. Model A was constructed to determine the minimum total budget that needs to be put aside by U-XYZ in order to achieve its target for research and publication agenda. Model B on the other hand was constructed to determine the proper strategy for U-XYZ to employ to maximize the total rating score obtained, subject to the total budget allocated by U-XYZ. The two models are illustrated next.
Model A: To determine the minimum budget required to fulfil all the KPIs.
Decision variables:

x_i = total output *i* to produce where *i* = A,B,C,D,E

Objective function:

Minimize total budget required = f(x)

where
$f(x) = 125{,}000x_A + 1{,}000x_B + 500x_C + 2{,}000x_D + 100x_E$

Subject to these following constraints:
Total points to be achieved for each strategy *i*.

$0.000800x_A \geq 0.0528$

$0.000625x_B \geq 0.75$

$0.000625x_C \geq 0.75$

$0.000333x_D \geq 0.02$

$0.000333x_E \geq 0.02$

Model B: To maximize the total expected points obtained subject to the total budget allocated.
Decision variables:
x_i = total output *i* to produce where *i* = A,B,C,D,E
d_i = total difference between the total points achieved and the total expected points for each strategy *i* where *i* = A,B,C,D,E

Objective function:
Minimize total difference between total points achieved and total expected points = g(x), where

$g(x) = d_A + d_B + d_C + d_D + d_E$

Subject to these following constraints:
Total points to be achieved for each strategy *i*.
$0.000800x_A + d_A = 0.0828$

$0.000625x_B + d_B = 0.75$

$0.000625x_C + d_C = 0.75$

$0.000333x_D + d_D = 0.02$

$0.000333x_E + d_E = 0.02$

Total budget allocated by U-XYZ. We assumed that the total budget was RM8,000,000.00

$125{,}000x_A + 1{,}000x_B + 500x_C + 2{,}000x_D + 100x_E \leq 8{,}000{,}000$

STEP 4: What-if analyses

Two possible what-if analyses can be conducted. Here, we only tried two of the analyses.

i. Experiment 1: the reduction of budget allocation by 10 percent in Model B. and

ii. Experiment 2: the 10 percent increase in the cost of producing one output for each strategy in Model A.

5. Result and Discussion

As expected, the results produced by Model A are exactly as the targeted requirement that needs to be achieved by each strategy (as stated in Table 1), i.e. total new PhD holders = 66, total Scopus-indexed journal = 1200, total other- than-Scopus-indexed journal = 1200, total mobility students inbound = 60 and total mobility students outbound = 60. The total amount of budget required is RM10,164,600.00.

For model B, with a total allocated budget of RM8,000,000.00 which is lower than RM10,164.600.00 as proposed by Model A, U-XYZ can only expect to obtain 1.578 out of 1.593 points that is required to be achieved. The budget can only be allocated to produce 48 new PhD holders, 1190 Scopus-indexed journal articles, 1190 other-than-Scopus-indexed journal articles, 60 mobility students inbound, and 60 mobility students outbound.

For the first what-if analysis, it was found that with the reduction of 10 percent in the expected total budget to be allocated in order to achieve full-rating points, only 1.573 points can be achieved (as opposed to the previous 1.578 points) which is a decrease of only 1.25%.

For the second what-if analysis, with the increment of 10 percent each in producing one output under each strategy, the minimum total budget that must be allocated in order to achieve full-rating points is RM11,181,060.00. This results in exactly 10 percent increment from the previous minimum total budget.

6. Conclusion

In this paper, we illustrated how IP-model was utilised to help U-XYZ allocate its operating budget to achieve its research and publication agenda. Two models were developed. The first model was to determine the minimum total budget that U-XYZ should allocate if all the agendas were to be fully-fulfilled. The second model was to determine the exact best strategies for U-XYZ to achieve the most out of the total budget allocated by U-XYZ's treasurer. Both models produced an optimal solution, each. The two models would be more meaningful if the information regarding the total budget allocated by U-XYZ treasurer is provided. For future research, we recommend for the model to be expanded to include all the agendas under the university strategic plan.

References

[1] Hinton, Karen E. "A practical guide to strategic planning in higher education. Society for College and University Planning." *Ann Arbor. http:// oira. cortland. edu/ webpage/ planningandasses smentresources/ planningresource s/ SCPGuideonPlanni ng. pdf* (2012).

[2] "The national higher education action plan phase 2 2011-2015." Ministry of Higher Education, Malaysia. http://www.hu.ac.th/english/academic/documents/psptn2-eng.pdf, accessed on 10 July 2016.

[3] Ballard, Paul J. *Measuring performance excellence: Key performance indicators for institutions accepted into the Academic Quality Improvement Program (AQIP)*. Western Michigan University, 2013.

[4] Europeia, Comissão. "Assessing Europe's university-based research: expert group on assessment of university-based research." *Luxembourg: Publications Office of the European Union. Disponível em: http://ec. europa. eu/research/era/docs/en/areasof-actions-universities-assessing-europe-university-based-research-2010-en. pdf. Acesso em* 26, no. 06 (2010): 2012.

[5] Marginson, Simon. "Global university rankings: Implications in general and for Australia." *Journal of Higher Education Policy and Management* 29, no. 2 (2007): 131-142.

[6] "Budget 2017: public universities suffer almost 20pc spending cut." The Malay Mail, 22 October, 2016.

[7] Arena, Marika, and Michela Arnaboldi. "Debate: Dealing with spending reviews—Italy." *Public Money & Management* 33, no. 1 (2013): 4-6.

[8] Rowley, Jennifer. "Is higher education ready for knowledge management?." *International journal of educational management* 14, no. 7 (2000): 325-333.

[9] Arena, Marika, Michela Arnaboldi, Giovanni Azzone, and Paola Carlucci. "Developing a performance measurement system for university central administrative services." *Higher Education Quarterly* 63, no. 3 (2009): 237-263.

[10] Arena, Marika, Michela Arnaboldi, and Giovanni Azzone. "Student perceptions and central administrative services: the case of higher education in Italy." *Studies in Higher Education* 35, no. 8 (2010): 941-959.

[11] Welter, F., C. Jooß, A. Richert, S. Jeschke, and C. Brecher. “Organisation and management of integrative research.” In C. Brecher (Ed.) Integrative production technology for high-wage countries. Springer-Verlag, 2012.

[12] Smith, Neale, Craig Mitton, Laura Dowling, Mary-Ann Hiltz, Matthew Campbell, and Shashi Ashok Gujar. "Introducing new priority setting and resource allocation processes in a Canadian healthcare organization: a case study analysis informed by multiple streams theory." *International journal of health policy and management* 5, no. 1 (2016): 23.

[13] Polisena, Julie, Tammy Clifford, Adam G. Elshaug, Craig Mitton, Erin Russell, and Becky Skidmore. "Case studies that illustrate disinvestment and resource allocation decision-making processes in health care: a systematic review." *International journal of technology assessment in health care* 29, no. 2 (2013): 174-184.

[14] Sekar, I., and Timothy O. Randhir. "Spatial Risk Assessment of Farming on Wetland Habitats in Watershed System." *Water, Air, & Soil Pollution* 225, no. 9 (2014): 2116.

[15] Canadian Agency for Drugs and Technologies in Health. "Guidelines for the economic evaluation of health technologies: Canada." In *Guidelines for the economic evaluation of health technologies: Canada*. CADTH, 2006.

[16] Mak, Christine Suet Yee. "Evaluation of health programs: application of social cost benefit analysis in the Pharmaceutical Benefits Scheme listing of Australia." PhD diss., Victoria University, 2005.

[17] Goldstein, Itay, and Haresh Sapra. "Should banks' stress test results be disclosed? An analysis of the costs and benefits." *Foundations and Trends® in Finance* 8, no. 1 (2014): 1-54.

[18] Mishan, Edward J. *Elements of Cost-Benefit Analysis (Routledge Revivals)*. Routledge, 2015.

[19] Kind, Paul, Jennifer Elston Lafata, Karl Matuszewski, and Dennis Raisch. "The use of QALYs in clinical and patient decision-making: issues and prospects." *Value in Health* 12 (2009): S27-S30.

[20] Mitton, Craig, Francois Dionne, and Cam Donaldson. "Managing healthcare budgets in times of austerity: the role of program budgeting and marginal analysis." *Applied health economics and health policy* 12, no. 2 (2014): 95-102.

[21] Golan, Ofra, Paul Hansen, Giora Kaplan, and Orna Tal. "Health technology prioritization: which criteria for prioritizing new technologies and what are their relative weights?." *Health policy* 102, no. 2 (2011): 126-135.

[22] Editing Team of Operational Research Teaching Material. Operational research (3rd edition). Tsinghua University Press, 2005.

[23] Taha, Hamdy. Operations research: an introduction (8th edition). Prentice Hall, 2007.

[24] Little, J., P. Knights, and Erkan Topal. "Integrated optimization of underground mine design and scheduling." *Journal of the Southern African Institute of Mining and Metallurgy* 113, no. 10 (2013): 775-785.

[25] G. Laporte, Y. Nobert, Generalized traveling salesman through n sets of nodes: an integer programming approach, INFOR 21 (1983) 61-75.

[26] S. Arya. “An optimal instruction-scheduling model for a class of vector vrocessors.” IEEE transactions on computers C-34, no. 11 (1985):981-995.

[27] Ramli, Razamin, Faathirah Jamaluddin, Engku Muhammad Nazri, Engku Abu Bakar, Mohamad Yusoff Alias, Nor Idayu Mahat, and Mohd Zaini Abdul Karim. "Assignment of Spectrum Demands by Merits Via Analytic Hierarchy Process and Integer Programming." *Journal of ICT* 12 (2013): 39-53.

[28] Nazri, E. M and R. Ramli. “The assignment of atudents to group activities using integer programming.” In 0perational 0esearch and its applications: recent trends (APORS 2003), Vol. 11. Allied Publishers Pvt. Limited, 2003.

[29] El Karim, A., R. Ramli, E. M. Nazri, and A, Choi Leng. “Course assignment: an integer programming model with time-based preference.” Jurnal KALAM 2, No. 1 (2009): 29-38.

[30] Daskalaki, Sophia, Theodore Birbas, and Efthymios Housos. "An integer programming formulation for a case study in university timetabling." *European Journal of Operational Research* 153, no. 1 (2004): 117-135.

[31] Earnshaw, Stephanie R., and Susan L. Dennett. "Integer/linear mathematical programming models." *Pharmacoeconomics* 21, no. 12 (2003): 839-851.

[32] Jamison, D.T., H.W. Mosley, A.R. Measham, and J.L. Bobadilla, eds. Disease control priorities in developing countries. Washington, DC: World Bank, 1993.

[33] Geoffrion, Arthur M., and Roy EARL Marsten. "Integer programming algorithms: A framework and state-of-the-art survey." *Management Science*18, no. 9 (1972): 465-491.

[34] Yavuz, Serdar, and T. A. Captain. "Making project selection decisions: a multi-period capital budgeting problem." *International Journal of Industrial Engineering* 9, no. 3 (2002): 301-310.

[35] Bowman Jr, V. Joseph. "Sensitivity analysis in linear integer programming." *AIIE Transactions* 4, no. 4 (1972): 284-289.

[36] Siddiqui, Azra, and Shumail Ahmad Siddiqui. "Linear and Integer Programming with Sensitivity Analysis Approach."

[37] Simpson, Annie N., Heather S. Bonilha, Abby S. Kazley, James S. Zoller, and Charles Ellis. "Marginal costing methods highlight the contributing cost of comorbid conditions in Medicare patients: a quasi-experimental case–control study of ischemic stroke costs." *Cost Effectiveness and Resource Allocation*11, no. 1 (2013): 29.

[38] Finney, Robert G. "Budgeting: From pain to power." *Management review* 82, no. 9 (1993): 27.

[39] Campbell, Ian J. "Budgeting: is it a technical or behavioural process." *Management Accounting* (1985): 66-70.

[40] Choi, B.S. and W.K. Lim. “A study on the optimal allocation of budget for the efficiency of the university evaluation.” Journal of the Korea society of computer and information 18, No. 7 (2013): 165-174.

[41] Aziz, R. Wan Abdul, A. Shuib, A. H. Nawawi, and N. Mohd Tawil. "Mathematical Model for Budget Planning and Execution." *Journal of Industrial and Intelligent Information Vol* 3, no. 2 (2015).

[41] Koch, James V. "A linear programming model of resource allocation in a university." *Decision Sciences* 4, no. 4 (1973): 494-504.