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A Conceptual Overview on Quantitative Models in Higher Education's Budget Planning

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Abstract: Managing budget at institution of higher learning is a complex multi-level resource allocation problem where competition and balancing acts are involved at various levels. This study provides a literature review on the applications of Mathematical Programming (MP) in budget planning. It will analyze which variants of MP are the most commonly used and their applications in budget planning in institution of higher learning. It is observed that goal programming constitutes the highest number of mathematical programming model proposed to handle resource allocation and budgeting problem in institution of higher learning.

Key words: Budget planning, budgeting, resource allocation, mathematical programming, higher learning

INTRODUCTION

A financial management in an organization is always perceived as a complex Decision Making (DM), especially when it involves allocating budget to a large number of departments which vary in terms of their spending expenditures. Generally, the budget given is never sufficient to accommodate all the requests. DM in budget distribution often requires allocation tradeoffs between departments and between items listed in the funding requests of the departments (Kocamustafaogullari, 2009). Budget planning or simply budgeting is concerned with planning the allocation and spending of resources to meet certain goals (Xavier, 2002). Budget planning is important in resource allocation in order to allow the organization to set priorities towards achieving these goals and to identify highest priorities to be accomplished with the available funds.

Adekanmbi and Boadi (2008) define budgeting as a financial plan that is mostly used in organizations. It is a useful tool for planning and efficiency which provides guidelines for management in terms of both spending limits and priorities for spending (Dixon, 2003). Many budget planning involves optimally allocating resources. One of the advantages of budget planning is that a decision maker can systematically plan the proportion of budget to be allocated for the identified budget activities to match with the objectives and strategic plans of the respective department or organization. A lot of researches that studied budget planning and resource allocation can be found since mid 60's (Wetherbe and Dickson, 1979; Adekanmbi and Boadi, 2008; Dixon, 2003; Wetherbe and Dickson, 1979; Arbel, 1983; Clarke, 1997; Kwak and Lee, 1998; Verheyen, 1998; Caballero *et al*., 2001; Sun, 2002; Ho *et al*., 2006; Nopiah *et al*., 2007; Kaka and Khosrowshahi, 2009; Webb and Candreva, 2010; Dellaert *et al*., 2011; O'Meara *et al*., 2011).

The purpose of this study is to provide a structured literature review on the applications of MP in budget planning. This study identifies which variants of MP that are the most commonly used and discusses their applications in budget planning of the institutions of higher learning.

MATHEMATICAL PROGRAMMING MODELS

According to Mulvey and Shetty (2004), there are four main elements that can be integrated in the budget planning system. These four elements are as shown in Fig. 1. Development of a mathematical model is an

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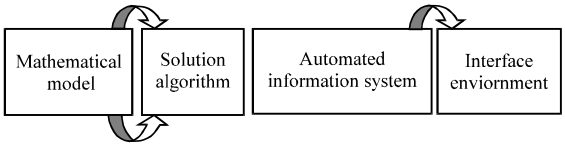

Fig. 1: Main elements in budget planning system

essential part in establishing a budget planning system. In fact, it is the ground to solving many real world problems. In this study, mathematical models for solving resource allocations and budget planning are classified into two groups; Mathematical Programming (MP) models and other models such as data envelopment analysis, stochastic frontier analysis, multistage, etc. An MP is comprised of an objective function which is a mathematical expression of the quantity to be maximized or minimized and constraints which are the mathematical expressions of restrictions that are placed on potential values of the objective function. Sun (2002) mentioned three advantages of MP approach that include its ability to handle restriction, the results obtained are less sensitive to outliers in the data set because MP minimizes the absolute deviations rather than the squared deviations as in regression analysis and finally, its flexibility especially in the Multiple Objective Programming (MOP) where the DMs preferences are incorporated when the parameters in the model are being estimated.

Most MP approaches that have been utilized in budget and resources allocation are linear programming (Verheyen, 1998; Chien *et al*., 1999; Baldacci *et al*., 2009; Amirteimoori and Tabar, 2010; Zeynalian *et al*., 2010), goal programming (Kwak and Lee, 1998; Caballero *et al*., 2001; Sun, 2002; Nopiah *et al*., 2007; Awoingo, 2010; Makui *et al*., 2008; Caballero *et al*., 2004; Badri, 1999; Kwak and Diminnie, 1987; Greenwood and Moore, 1987; Soyibo and Lee, 1986; Keown *et al*., 1981; Schroeder, 1974; Lee and Clayton, 1972), analytic hierarchical process (Arbel, 1983; Kwak and Lee, 1998; Badri, 1999; Frezatti *et al*., 2011; Jeng and Chiu, 2010; Rammanathan and Ganesh, 1995; Greenberg and Nunamaker, 1994) while multi-objective multi-stage decision making, multi-criteria programming, multi-linear programming and multi-integer goal programming which can be classed as multi-criteria decision making have been extensively used (Sun, 2002; Zeynalian *et al*., 2010; Keown *et al*., 1981; Greenberg and Nunamaker, 1994; Moheb-Alizadeh *et al*., 2011; Morcos, 2008; Lin and Gen, 2007, Dejenee, 2007; Palaniappan *et al*., 2001). These are shown in Fig. 2.

Linear programming: Optimization problems that has a linear objective function, linear constraints and the non-negativity constraints on all the decision variables is

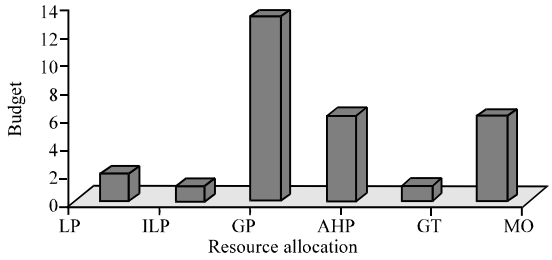

Fig. 2: Mathematical programming models in budget and resource allocation; LP: Linear Programming; ILP: Integer Linear Programming; GP: Goal Programming; AHP: Analytic Hierarchy Process; GT: Game Theory; MO: Multi-Objective decision making

known as Linear Programming (LP) (Srinivasan, 2007). Based on the review, researchers only found two researchers, Baldacci *et al*. (2009) and Verheyen (1998) who utilized LP in budgeting. Verheyen (1998) analyzed the multi-level decision structure of national budget in non-profit institution through combination decision of the top management and base level professional in budget system allocation. On the other hand, Baldacci *et al*. (2009) applied the LP Model using both heuristic and exact method to solve a large scale multi-period financial planning problem. They found that LP is impractical to solve even for small instances because the number of variables of formulation grows exponentially with the number of periods and the number of realizations at each time instant. However, they agreed that the structure of the constraints matrix is suitable for the application of decomposition techniques such as Lagrangian relaxation, Dantzig-Wolve and Benders' decompositions. In their study, they proposed a Criss-Cross Generation Method where both primal and the dual structure of the problem were exploited simultaneously to solves a difficult instance which cannot be solved using LP solvers of CPLEX. Furthermore, the Criss-Cross Generation Method has the ability to converge quickly to a solution.

Chien *et al*. (1999) applied the neural network algorithm on an Integer Linear Programming (ILP) Model that they developed to optimize annual budget allocation in Taiwan's food industry. The ILP Model significantly reduced the time spent in the evaluation and selection of best strategies proposed for the Strategic Business Units (SBUs) of the industries. The researchers stated that the mathematical programming technique is capable of providing a powerful tool in selecting the best strategic plans if fully understood and utilized by the managers.

Considering allocating funds for organizations with large scale can be handled in a hierarchical form,

Zeynalian *et al.* (2010) have proposed the multi-level multiple goal programming model which is solved using weighted sum linear programming approach method to solve budget allocation within a large scale hierarchical organization. The model aims at maximizing the productivity and efficiency of the budget allocated. Finally, Amirteimoori and Tabar (2010) have used an integer valued Data Envelopment Analysis (DEA) to determine the optimal allocation for allocating a fixed resources (costs) across a set of decision making units involving 20 gas companies located in 18 regions in Iran. Using the model, the output targets can be decided simultaneously with decisions being made on the resource allocation.

Multi-criteria decision making: Multi-criteria Decision Making (MCDM) Method has been widely applied for decision making problems in various areas such as in higher education, agriculture, banking energy, forestry, health services, military and highway planning (Mustafa and Goh, 1996). A multiple criteria such as multiple decision makers, multiple objectives, multiple goals and priorities are often involved in allocating budget. Thus, there are many MCDM methods that can be found in the literature (Sun, 2002; Zeynalian *et al*., 2010; Keown *et al*., 1981; Greenberg and Nunamaker, 1994; Moheb-Alizadeh *et al*., 2011; Morcos, 2008; Lin and Gen, 2007; Dejenee, 2007; Palaniappan *et al*., 2001). These approaches can be classified into two categories. The first category is known as Multi-Objective Decision Making (MODM) (Triantaphyllou *et al*., 1998) which can be applied to find optimal solutions for problems with continuous integer or decision spaces. The second category called Multi-Attribute Decision Making (MADM) involves discrete decision spaces. According to Triantaphyllou *et al.* (1998) MADM can be classified according to the type of data used, the number of DM involved in decision process type of information and the salient feature of information.

In literature, the most popular MCDM methods applied in budgeting are Goal Programming (GP) and Analytic Hierarchy Process (AHP). Morcos (2008) employed an MCDM methodology to solve the problem of allocating constrained budget resources (investments) to different R&D projects portfolios and to select the efficient portfolios which match the R&D investments with the corporate long term objectives. The study applied a computer based multi-criteria approach that allows the decision maker to easily assess the impact of trading off R&D project portfolios tangible benefits (short term profits) and intangible benefits (reliability and risk) against constrained budget resources (investment costs), without the requirement for sophisticated and time consuming mathematical formulations. In addition, Mulvey and Shetty (2004) introduced a multi-stage Stochastic Programming Model to develop a financial plan that fits the investor's needs and capable of measuring the risk and rewards of alternative investment strategies.

Goal programming: Although, LP is a suitable technique to find optimization but in real world people deal with many objectives that involve multiple Decision Maker (DM). In real life situations, a DM may have multiple objectives with rigid and flexible constraints with a goal. Available resources are limited to meet desired goals, some goals have to eliminate by some decision making, some have to postpone and reduce others in order to achieve desirable goals into practical and feasible objectives. These situations are model using Goal Programming (GP). GP widely used in variety area such as resource scheduling university budgeting, balancing assignment designing public investment, measuring performance, staff scheduling, multinational acquisition analysis and information project selection (Kwak and Lee, 1998). GP is based on the concept of bounded rationality which concern with satisfying rather than optimizing approach (Aris *et al*., 2006), a special extension of linear programming and the most appropriate technique in developing a model to accomplish multiple, competitive and frequently conflicting goals with varying priorities (Lee and Clayton, 1972).

Analytic hierarchy process: AHP has been introduced by Saaty in 1980. AHP is a theory of relative measurement of tangible criteria where an Eigen value approach to the pair wise comparisons, Vaidya and Kumar (2006) enables the DM to structure a complex problem in the form of a simple hierarchy and to evaluate the large number of quantitative and qualitative factors in a systematic manner under various multiple criteria (Badri, 1999). This is a simple MCDM Method which deal with unstructured, multi-attribute problems (Rad *et al*., 2011) and consists of breaking down a complex problem into its component which are then organized into levels in order to generate a hierarchical structure. This method has been apply in various field such as planning, selecting the best alternatives, resource, allocations, resolving conflict, optimization and numerical extension of AHP (Vaidya and Kumar, 2006).

Frezatti *et al.* (2011) grouped the entities of strategic budget planning process to identify the planning profiles. They employed AHP to analyze the variables presented in the literature review. Jeng and Chiu (2010) used AHP to estimate the objective coefficients of the allocation model for a theme park ad budgeting problem. AHP also used for solving multi-criteria resource allocation problem by converting them into equivalent single objective maximization type LP problems (Rammanathan and

Table 1: Mathematical programming model in institution of higher learning

Researchers	Resource allocation	Budgeting	Case study: Institution of higher learning	Mathematical programming models						Other mathematical models
				LP	ILP	GP	AHP	GT	MO	
Alizadeh *et al.* (2011)	✓									-
Frezatti *et al.* (2011)		✓					-			
Amirteimori and Tabar (2010)		✓								-
Zeynalian *et al.* (2010)		✓								-
Jeng and Chiu (2010)		✓					-			
Maxwell and Awoingo (2010)		✓	✓			-				
Baldacci *et al.* (2009)		✓		-						
Lin and Gen (2008)	✓								-	
Kuo and Ho (2008)		✓	✓							-
Makui *et al.* (2008)	✓	✓				-				
Nopiah *et al.* (2007)	✓		✓			-				
Lin and Gen (2007)	✓	✓							-	
Dejenee (2007)		✓	✓					-		
Lee and Lee (2005)	✓									-
Caballero *et al.* (2004)		✓	✓			-				
Sun (2002)	✓		✓			-			-	
Caballero *et al.* (2001)		✓	✓			-				
Palanappian *et al.* (2001)	✓								-	
Mulvey and Shetty (2004)	✓								-	
Chien *et al.* (1999)		✓		-						
Badri (1999)	✓					-	-			
Verheyen (1998)		✓	✓	-						
Kwak and Lee (1998)	✓		✓			-	-			
Rammanathan and Ganesh (1995)	✓						-			
Greenberg and Nunamaker (1994)		✓	✓				-		-	
Greenwood and Moore (1987)		✓	✓			-				
Kwak and Diminnie (1987)		✓	✓			-				
Soyibo and Lee (1986)	✓		✓			-				
Keown *et al.* (1981)		✓	✓			-				
Schroeder (1974)		✓	✓			-				
Lee and Clayton (1972)	✓		✓			-				

LP: Linear Programming; ILP: Integer Linear Programming; GP: Goal Programming; AHP: Analytic Hierarchical Process; GT: Game Theory; MO: Multi Objective programming

Ganesh, 1995). Greenberg and Nunamaker (1994) develop and apply a multi-objective budgeting approach which attempts to alleviate scarce budgetary funds among competing activities and function. The selected components of a budget model where the required historical data are non-existent are estimate using AHP.

APPLICATIONS IN HIGHER LEARNING INSTITUTION

Most of the resource allocation and budgeting studies in Institution of Higher Learning (IHL) have been proposed using GP approach (Lee and Clayton, 1972; Schroeder, 1974; Keown *et al*., 1981; Soyibo and Lee, 1986; Kwak and Lee, 1998; Greenwood and Moore, 1987; Kwak and Diminnine, 1987; Caballero *et al*., 2001; Sun, 2002; Caballero *et al*., 2004; Nopiah *et al*., 2007; Awoing, 2010). A few studies on AHP Model in IHL (Arbel, 1983; Greenberg and Nunamaker, 1994; Kwak and Lee, 1998) and MCDM (Dejenee, 2007; Greenberg and Nunamaker, 1994; Sun, 2002). Only one paper utilizes LP (Verheyen, 1998). They studied problems such as resource allocation in university management, university capital budgeting, monetary allocation, network planning, academic resource planning and university tuition and fee structures. Most of the studies contribute in budget planning by employing models which optimize budget resource allocations but none addressed the budget execution model. Thus, the future study will be concerned with the development of a budget optimization model which incorporates budget execution constraints. This study explores resource allocation and budgeting in IHL and the utilization of mathematical models. Table 1 shows some of mathematical model that extensively used in IHL in a study of resource allocation and budgeting.

GP Model is utilized by Lee and Clayton (1972) in academic resource allocation. In their study, they found that GP is the best solution under the given constraints and priority structure. On the other hand, two serious limitations in resource management problem of academic unit that is budget levels and faculty levels is solved using GP approach by Schroeder (1974). The researcher concentrates on three variables (faculty, staff and teaching assistants levels) and three academic units only.

To the ends, the researchers found two strengths in GP. It is an excellent flexibility in considering alternative goal levels priorities and budgets and is able to handle

large amounts of data by many trade off that can be considered automatically. Soyibo and Lee (1986) expanded Schroeder (1974)'s research by applying GP to seven faculties and a College of Medicine in University of Ibadan, Nigeria. In the model, they define a student enrollment goal an academic staff level goal and the academic rank mix goal excluded of support staff. In their research, Markovian parameter estimation and simple statistical estimation are used. The linear programming revised simplex method in the product of Gauss-Jordan form with the Lee Algorithm in 1972 is combined with arthur and Ravindram Algorithm (1978) are used to solve a large scale academic resource allocation planning problem. The results show that CPU time and internal storage requirements had been reduced and these computations are more efficient.

Keown *et al.* (1981) demonstrates the applicability of mixed integer GP to reflect the unique characteristic of university capital budgeting problem. About 22 proposed studies are involved concerning cost and operating expenses. This model allowed the complexities such as multiple conflicting goals, indivisibility of projects, capital rationing and the unique decision making environment where the university administrators demonstrate to requiring integer solution. On the other hand, GP Model is applied by Kwak and Diminie (1987) for reducing the operating budget of the academic units of St, Bonaventure University. They develop zero-one GP to solve the model and it's revealed the distribution of budget reductions among the schools and within the departments.

GP is found provides a rational, tractable and flexible for administrator to analyze and establishing tuition charges. This approach is implemented in Greenwood and Moore (1987) research by using a multi-goal linear programming model in allocation of institution's annual tuition charges by category of student which is based on a set of university goals, constraints and priorities. It is found that GP as a useful instrument for efficient assignment of the financial resources in university system (Caballero *et al*., 2001). In this study, the model covers the most urgent teaching needs encourages the units to achieve greater research potential and improved staff quality.

Sun (2002) present budget allocation for faculty salary equity adjustment using interactive multiple objective programming approach. The researchers also classifies the faculty members as underpaid faculty members and overpaid faculty members. The researcher found that the model is a convenient decision support tool for the DMs to explore different options in the decision process by reformulates the model such as adding, deleting and/or modifying constraints that will reflect the budgetary and policy restrictions of the institution. The weakness in GP is found in this study where in the solutions GP priorities and/or weights usually are assigned to different goals can only find the basic solutions defined by constraints. But, the best solutions are not necessarily a basic solution. To this end, three suggestions are given. These are determinant of faculty salary and the variables to be included in the model, model comparison and determine the terms of variables in the model such as quadratic terms cubic terms and nonlinear terms. On the other hand, Caballero *et al.* (2004) integrate GP and DEA to demonstrate the complementary relation that exists between the approaches for the planning of academic human resources within a university. This approach has been applied in 3 steps. In the 1st step, DEA is applied to evaluate the productivity of university human resources. Then, GP is utilized for new resources allocation and finally DEA is applied again to analyze the new input and output of allocation. The researchers found two benefits from this approach. These are a valid tool to detect an efficiencies and/or inefficiencies and to determine the link between the allocation of resources to the departments and their average improvement. Nopiah *et al.* (2007) utilized GP Model for resource allocation problem in university management for better academic performance.

Lastly, Awoingo (2010) formulate GP Model for budgeting in Rivers State University of Science and Technology and converted it to LP Model and solve the weights of LP Model using simplex method (Big M). The researchers used five variables in the model that is personal cost (salary and allowance staff), overhead cost, capital expenditure, revenue (internal generated) and total budget. The optimization results show that all goals are satisfied except the revenue goal. As a result, GP is a useful method for resources allocation with different knowledge areas (Caballero *et al*., 2001) that can serve as a conflict resolution devise where in each conflicting interest groups have their own goals and priorities will contribute a successful planning aid with high level support in management team participation (Batson, 1989).

Budget allocation is said under limited resources when the total schools budget is less then total request for appropriations. These are a university budgeting problem that concerned with AHP Approach in a study by Arbel (1983). In this study, the researcher focus on teaching and research activities by present budget allocation model that based on prioritizing the six departments by considering their benefit to the schools future evolution and their cost of operations. He structured the budget model in four levels that is school's budget, goals, supporting factors and departments' contribution.

On the other hand, Greenberg and Nunamaker (1994) utilized AHP to develop and apply multi-objective budgeting approach that attempts to alleviate the problems when performance data needed to specify certain elements of the models are often inadequate or unknown. In Kwak and Lee (1998), GP, AHP and sensitivity analyses are integrated in allocating university resources related to network planning. These are integrates by developing and analyzed zero-one GP to address the dramatic increase in information technology use and network planning then proper weights are assign to prioritized project goals by using AHP and lastly the model applicability is improved by sensitivity analyses.

Verheyen (1998) studied the problems of Dutch University and hospitals. He conclude that in a pure budget system the tasks should be decide by professional while the amount of money have to be decide by the management but both of them must work together in a budget approach with one goal that is the core process of the non profit organization.

OTHER MATHEMATICAL MODEL

Other mathematical models such as data envelopment analysis (Amirteimoori and Tabar, 2010; Moheb-Alizadeh *et al*., 2011), statistics frontier analysis (Kuo and Ho, 2008), statistical cluster analysis (Frezatti *et al*., 2011) and dynamic stochastic programming (Mulvey ans Shetty, 2004) are used in allocate resources. These models will not be discussed in this study.

CONCLUSION

Managing the budget is a critical task for financial decision making. As a result of scarcity resources in institution of higher learning today, the universities face difficulties in receiving levels of funding. Poor budgeting plan may affect the universities productivity and the DMs credibility. This will also give major implication towards the university's overall budget performance. Thus, effective budget plan and management is vital for optimum budget performance. The variety of the reported mathematical models proposed in resource allocation and budgeting problem in institution of higher education, clearly indicates the significant contribution that MP has made in institution of higher learning. It is hoped that this study will provide a guide for developing an efficient model for managing utilization of budget allocations such that faculties and universities priorities are catered and strategic goals are achieved.

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