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An Integer Linear Programming based Optimal Faculty Training Strategy: A Case Study

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Abstract: The ability of appropriate decision making is crucial to the success of an organization. Decision- making requires the identification of all alternatives of the problem and selecting the best of the available alternatives. The application of operations research techniques helps seeking the optimal choice from among several possible alternative courses of action or strategies. This piece of work aims to determine the optimum number of faculty members (lecturers, assistant professors, associate professors and professors) to be selected for a faculty training program, from amongst the four Faculties of Mehran University of Engineering and Technology, Jamshoro, with the intent to minimize the cost of training. This paper presents a mathematical model for each of the four Faculties of the University. Integer Linear Programming (ILP), an operations research technique, was used to solve the models to achieve the optimum results.

Keywords: Training, operations research, integer linear programming, linear programming

1. INTRODUCTION

Decision-making is a vital aspect in the context of complex managerial tasks. The effective functioning of an organization depends to a large extent on making right decisions; whereas wrong decisions can have far-reaching consequences (Rao, 2005). Tentative decisions cannot be made on a trial-and-error basis, intuition, guesswork or personal judgment etc. Hence, an understanding of the applicability of scientific or quantitative techniques is of fundamental importance to decision-makers (Valero, 1997). The practice of operations research techniques in this respect provides a scientific approach to make effective and appropriate decisions (Rao, 2005).

There are four teaching Faculties in Mehran University of Engineering & Technology, Jamshoro, namely, (i) Faculty of Engineering, (ii) Faculty of Electrical, Electronic and Computer Engineering, (iii) Faculty of Architecture and Civil Engineering and (iv) Faculty of Science, Technology and Humanities. These four Faculties comprise of seven, six, four and three teaching departments/institutes respectively. A total of 282 members of teaching faculty (including lecturers, assistant professors, associate professors and professors) are serving in various departments/institutes functioning under the above mentioned four Faculties.

It is highly required from the members of teaching faculty to impart quality education and to play a leadership role to their students during their learning phase. Training of faculty members, therefore, is an essential factor that helps them in fostering their skills and capabilities that leads to a more efficient and skillful performance. Faculty training in this respect is an innovative process which provides far efficient learning outcomes for the faculty members and in turn, the students (Fink *et al.*, 2003). Faculty training programs cater to the need of motivating the faculty members to groom themselves professionally.

One of the most important aspects of faculty training is the cost involved. The University aims to utilize all human as well as material resources optimally in order for accruing the maximum benefit. The objective of this work is to determine an effective strategy for selecting the faculty members for the training program which, on one hand, can minimize the cost of training and, on the other hand, can make it feasible for all the Faculties to be well represented.

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2. MATERIL AND METHODS

2.1 Methodology

In this piece of work quantitative research methodology was adopted. In order to pursue the objective of this work, data was collected, classified and a mathematical model was formulated for each of the four Faculties of the University. Prospectus (2010-2011) for Bachelor Degree Program of the University was referred to collect the data. The data collected included the number of Faculty members (lecturers, assistant professors, associate professors and professors) serving in various departments/institutes under each of the four Faculties.

2.2 Model Assumptions

The mathematical models in this piece of work were formulated on the basis of following assumptions:

- The training program continues for 14 days.
- The cost of training one faculty member is assumed to be $Rs.\ 3500$, irrespective of whether the faculty member is a lecturer, an assistant professor, an associate professor or a professor.

2.3 Tools and Techniques

Integer Linear Programming (ILP) Technique was used to formulate the mathematical models which were solved using TORA Software.

2. Literature Review

The word operations research was coined during World War II, when the British military management formulated teams of scientists having diverse educational backgrounds to analyze the tactical and strategic matters concerning land and air defense and carry out research in military operations with the purpose of winning the war (Ravindran *et al.,* 2001). The primary objective was to allocate the limited resources of war material in an efficient manner to various military operations and to the different activities within each operation.

After the war, the effectiveness of OR in military operations led to its spread in government departments, industrial, social and economic planning (Gupta and Hira, 2007). Many operations researchers continued their research after the war. A revolutionary development took place in 1947 when G.B. Dantzig proposed linear programming technique (Dantzig, 2002). Linear programming is a resource allocation technique used to determine the optimum allocation of scarce or limited resources, which may include manpower, time, money, space, raw materials, machinery etc, to a number of competing demands (Gupta and Hira, 2007). Linear programming is used to optimize (minimize or maximize) a linear function known as an objective function whose variables called decision variables are subject to a set of certain restrictions/limitations called constraints expressed in the form of linear equations or linear inequalities. If some or all the decision variables in a linear programming problem are restricted to take integer values only, the problem is then referred to as an integer linear programming (ILP) problem (Taha, 1994).

Due to the availability of fast computing facilities, LP and ILP are widely used in the area of personnel management for manpower planning, resource allocation, staffing and scheduling of training programs. Purkiss (1969) in a study used linear programming technique to minimize the total cost of an industrial training organization in recruitment, training, transfers and redundancy. (Murty *et al.,* 1995) used Mixed Integer Programming (MIP) technique to determine an optimal training strategy for a battalion comprising on 232 soldiers to minimize the training cost. (Mohammadpour *et al.,* 2008) developed and solved a linear programming model which combined training and hiring labor in different skills for a construction project to reduce and control the training and hiring costs. (Fagoyinbo and Ajibode 2010) applied Linear Programming technique to find the least cost strategy for training staff members in the academic and non-academic sections of a Polytechnic institution.

3. Data Presentation

The data used for this piece of work is secondary data obtained from Prospectus (2010-2011) of the University. The data is given in **(Table 1)** which presents the number of lecturers, assistant professors, associate professors and professors serving in various departments/ institutes of the University.

Table 1: List of members of teaching faculty of the University

Department	No. Of Lecturers	No. Of Assistant Professors	No. Of Associate Professors	No. Of Professors
Faculty Of Engineering				
Dept. Of Chemical Engineering	6	4	1	1
Dept. Of Industrial Engineering and Management	5	4	1	2
Dept. Of Mechanical Engineering	2	10	6	2
Dept. Of Metallurgy & Materials Engineering	3	5	1	1
Dept. Of Mining Engineering	3	5	1	2
Dept. Of Textile Engineering	12	2	-	1
Institute Of Petroleum andNatural Gas Engineering	7	4	2	2
Faculty Of Electrical, Electronic and Computer Engineering				
Dept. Of Electrical Engineering	13	5	3	2
Dept. Of Biomedical Engineering	8	1	-	-
Dept. Of Computer Systems Engineering	9	6	1	2
Dept. Of Electronic Engineering	10	10	-	2
Dept. Of Software Engineering	8	1	1	1
Dept. Of Telecommunication Engineering	11	2	2	1
Faculty Of Architecture and Civil Engineering				
Dept. Of Architecture	7	8	1	-
Dept. Of City & Regional Planning	2	2	1	1
Dept. Of Civil Engineering	2	6	9	8
Institute Of Environmental Engineering and Management	-	2	-	2
Faculty Of Science, Technology annd Humanities				
Dept. Of Basic Sciences & Related Studies	12	8	1	2
English Language Development Centre	5	2	-	-
Mehran University Institute Of Science and Technology Development	-	4	-	3

Source: Prospectus (2010-2011), Bachelor Degree Program, Mehran University of Engineering and Technology, Jamshoro

4. Model Formulation

The decision variables used to formulate the mathematical models are x_1, x_2, x_3 and x_4 which denote the number of lecturers, assistant professors, associate professors and professors respectively to be selected for the faculty training program from each of the four Faculties of the University. The objective is to minimize the cost of training. The constraint in this study is the time duration for the training program.

4.1 Faculty of Engineering

Minimize $Z = 3500\left(x_1 + x_2 + x_3 + x_4\right)$

Subject to:

$6x_1 + 4x_2 + x_3 + x_4 \geq 14$

Department of Chemical Engineering

$5x_1 + 4x_2 + x_3 + 2x_4 \geq 14$

Department of Industrial Engineering

$2x_1 + 10x_2 + 6x_3 + 2x_4 \geq 14$

Department of Mechanical Engineering

$3x_1 + 5x_2 + x_3 + x_4 \geq 14$

Department of Metallurgy and Materials Engineering

$3x_1 + 5x_2 + x_3 + 2x_4 \geq 14$

Department of Mining Engineering

$12x_1 + 2x_2 + x_4 \geq 14$

Department of Textile Engineering

$7x_1 + 4x_2 + 2x_3 + 2x_4 \geq 14$

Institute of Petroleum and Natural Gas Engineering

$x_1, x_2, x_3, x_4 \geq 0$ and integers

4.2 Faculty of Electrical, Electronic & Computer Engineering

Minimize $Z = 3500\left(x_1 + x_2 + x_3 + x_4\right)$

Subject to:

$13x_1 + 5x_2 + 3x_3 + 2x_2 \geq 14$

Department of Electrical Engineering

$8x_1 + x_2 \geq 14$

Department of Biomedical Engineering

$9x_1 + 6x_2 + x_3 + 2x_4 \geq 14$

Department of Computer Systems Engineering

$10x_1 + 10x_2 + 2x_4 \geq 14$

Department of Electronic Engineering

$8x_1 + x_2 + x_3 + x_4 \geq 14$

Department of Software Engineering

$11x_1 + 2x_2 + 2x_3 + x_4 \geq 14$

Department of Telecommunication Engineering

$x_1, x_2, x_3, x_4 \geq 0$ and integers

4.3 Faculty of Architecture and Civil Engineering

Minimize $Z = 3500\left(x_1 + x_2 + x_3 + x_4\right)$

Subject to:

$7x_1 + 8x_2 + x_3 \geq 14$

Department of Architecture

$2x_1 + 2x_2 + x_3 + x_4 \geq 14$

Department of City and Regional Planning

$2x_1 + 6x_2 + 9x_3 + 8x_4 \geq 14$

Department of Civil Engineering

$2x_2 + 2x_4 \geq 14$

Institute of Environmental Engineering and Management

$x_1, x_2, x_3, x_4 \geq 0$ and integers

4.4 Faculty of Science, Technology and Humanities

Minimize $Z = 3500\left(x_1 + x_2 + x_3 + x_4\right)$

Subject to:

$12x_1 + 8x_2 + x_3 + 2x_4 \geq 14$

Department of Basic Sciences and Related Studies

$5x_1 + 2x_2 \geq 14$

English Language Development Centre

$4x_2 + 3x_4 \geq 14$

Mehran University Institute of Science and Technology Development

$x_1, x_2, x_3, x_4 \geq 0$ and integers

3. RESULTS AND DISCUSSION

The integer linear programming models formulated above were solved using TORA software and the results obtained are given in **(Table 2)**.

Table 2: Optimal Faculty Training Strategy

Name Of Faculty	No. Of Lecturers x_1	No. Of Assistant Professors x_2	No. Of Associate Professors x_3	No. Of Professors x_4	Cost OfT training (In Rs) Z
Faculty Of Engineering	1	2	1	0	14000
Faculty Of Electrical, Electronic and Computer Engineering	2	0	0	0	7000
Faculty Of Architecture and Civil Engineering	0	7	0	0	24500
Faculty Of Science, Technology and Humanities	2	2	0	1	17500

The above results show that from the Faculty of Engineering, one lecturer, two assistant professors and one associate professor should be selected for the faculty training program and this will cost Rs. 14, 000. From the Faculty of Electrical, Electronic and Computer Engineering, two lecturers must be selected for the training program and this will cost Rs. 7, 000. From the Faculty of Architecture and Civil Engineering, it is recommended to select seven assistant professors and it will lead to the training cost of Rs. 24, 500. Finally, for the Faculty of Science, Technology and Humanities, it is recommended to select two lecturers, two assistant professors and one professor for the training program and the training cost incurred in this respect will be Rs. 17, 500.

6. CONCLUSION

The objective of this work is to determine an optimal strategy for Faculty training in Mehran University of Engineering and Technology, Jamshoro which minimizes the cost of training. The study uses four decision variables: x_1, x_2, x_3 and x_4 which denote the number of lecturers, assistant professors, associate professors and professors respectively to be selected for the faculty training program. Integer linear programming (ILP) technique is used to formulate the mathematical models which are solved using TORA Software. The results obtained from these models provide the optimum number of lecturers, assistant professors, associate professors and professors to be selected for the training program from each of the four teaching Faculties of the University, along with the cost incurred owing to their training.

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