Optimizing College Degree Plan

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Abstract - **This paper deals with applying the quantitative analysis technique to the MBA program in order to identify the courses that a student must enroll in each semester to complete the degree in a timely manner. The critical path method (CPM) is commonly implemented in project management to determine the critical activities in a project's life. The CPM identifies a route which is necessary for timely completion of a given project. There are thirty six graduate and thirty under-graduate credit hours required to complete the MBA degree. The thirty under-graduate credit hours are pre-requisites for students with a non-business background. Twenty four out of thirt`y six graduate hours are required and the rest are electives. Some of the courses are offered each semester (Fall & Spring) and some are offered on an alternate basis, such as spring semester only or fall semester only. The pre-requisites, electives, and semester offerings are the constraints in this problem. This problem is formulated in a linear programming format with mathematical equations including an objective function and constraints. The time to complete a degree is major concern for each student because of the financial and time constraints. The CPM technique would be applied for a practical situation to advice students. This technique can also easily handle the situations that if the degree plan changes or if the student could not satisfy the initial degree plan and wants continuation. The results identify the courses that should be taken in each semester for a timely completion.**

Keywords - Degree Plan; Optimization; Critical Path Method; Linear Programming; Shortest Path; MBA program; Academic Advising

1.INTRODUCTION

As students go to a college, most of them want to complete their degree as soon as possible and get a job. In the project management point of view, to complete their degree is a project and the time to finish the project is critical (Badiru, 2012 & Marakas, 2003). The critical path is the shortest time to finish a project while satisfying all requirements (Pinto, 2010). The identification of the critical path is very important whenever a project involves more than one activity, such as courses to take in this case, for completion and the activities are inter-related (Rardin, 1998). The scenario of pre-completion of some activities before other activities creates a complex overall structure (Guerriero and Talarico, 2010). The critical path method (CPM) allows for simplification of such a structure by defining the activities from the beginning to the ending depending on the basis of precedence and dependence among all activities (Pinto, 2010).

The degree plan for an MBA student involves a number of courses which require pre-requisites and are offered on alternate semesters. A student must decide on appropriate courses to enroll in so they will not lack any pre-requisite when enrolling in later courses. At the same time, a course not enrolled in during the fall semester may result in extra time consumption as it may not be offered again until the next fall semester.

In order to provide a simplified scheduling picture, the degree plan is expressed as a flow diagram and solved using linear programming (LP) technique. The paper discusses the brief background of CPM and LP and their respective applicability in this particular problem. The consideration of all the relevant constraints and introduction of necessary assumptions would lead to a general network diagram for the MBA degree plan.

The variables would be defined in order to equate the diagram in Linear Programming format. Because of the high number of variables and constraints, this diagram is not solved for the purpose of this paper due to the tediousness and time consumption involved in solving such an extended problem.

The general diagram would be simplified in terms of more simplified assumptions so that a simplified diagram based on precedence and time required could be drawn. LP equation would then be formulated for the simplified problem and then solved using LINDO® software. The results from the LINDO® would lead to the revelation of minimum time required for the successful completion of the MBA degree plan and the courses a student is required to take each semester.

2. BACKGROUND

The MBA degree plan, offered at Texas A&M University-Kingsville, Kingsville, TX, for students with non-business background requires completion of total of 66 credit hours. 30 credit hours out of the overall hours constitute 10 undergraduate courses which are termed as 'stem courses' or pre-requisites for the 12 graduate courses (36 credit hours). Out of the 12 graduate courses, 8 (24 credits) are required and 4 (12 credits) are electives. It is worth mentioning that some of the 'stem courses'are pre-requisites for other 'stem-courses' which necessitate a student to enroll in particular 'stem courses' before other courses can be enrolled in.

Every student enrolled as a graduate student in the Business Administration enrolls in the required courses as mentioned and necessitated by the department. But for the elective courses, a student can choose 4 courses out of a number of different courses. In other words required courses remain the same for all students, whereas electives can change from one student to another. In terms of selecting the pool of elective courses for this problem, only those courses have been chosen which have regularly been offered in the previous two years from 2010. And out of all the offered electives, only those have been selected which do not require pre-requisites in addition to the pre-requisites required for the 'required' graduate courses.

Table 1: MBA Course Catalogue

Courses (Activity)	Code Assigned (Activity name)	Pre-Requisite (Precedence activity)	Time Required	Semester Offered
Under Graduate				
ACCT 2301	A	-	1	
ACCT 2302	B	A	1	
ECON 2301	C	-	1	
ECON 2302	D	C	1	
MKTG 3361	E	-	1	
BLAW 3341	F	-	1	
FINC 3337	G	-	1	
BUAD 3335	H	-	1	
MGMT 3321	I	H	1	
CISA 1301	J	-	1	
Graduate-Required				
ACCT 5311	K	B	1	Fall only
MKTG 5361	L	E	1	Fall only
FINC 5331	M	G	1	Spring only
MGMT 5337	N	H	1	Spring only
MGMT 5322	O		1	Spring only
MGMT 5325	P	I	1	Fall only
ECON 5329	Q	D	1	Fall only
MGMT 5335	R	Last Semester	1	
Graduate-Electives				
ACCT 5307	S	B	1	Fall only
ACCT 5308	T	Last Semester	1	
CISA 5309	U	J	1	Fall only
CISA 5310	V	J	1	Fall only
CISA 5320	W	J	1	Spring only
CISA 5330	X	J	1	Fall only
MKTG 5363	AA	E	1	Spring only

All the courses have been coded alphabetically as different activities. The time required for each course (or activity) is allotted as 1 which stands for a semester (either Fall or Spring). There are some courses which are offered once a year or they are either Fall only or Spring only courses. All the data required for the background has been collected from the University resources mainly the graduate catalog for year 2008-09 and the university

website for the students. The registration section of the university website for the last two years has been researched upon in order to find all the relevant information regarding the under-graduate and graduate courses. The data describing the activity schedule, precedence activity, time required, and the semester constraint has been organized in the following table:

3. CRITICAL PATH METHOD AND LINEAR PROGRAMMING

The CPM was developed by James E. Kelly, Jr. and Morgan R. Walker in 1957 and the technique has been adopted by decision makers for scheduling and routing (Taha, 2007). The technique was first used in the DuPont Company in order to make the plant turnaround more efficient in terms of time and effort required (Hillier and Lieberman, 2010). The identification of critical activities for project completion was the main achievement of this technique which would in turn lead to the calculation of the shortest time to complete the project based on each time period associated with the critical activities (Balakrishnan et al, 2013). The technique sets up the project activities in terms of precedence and evaluates the route on the basis of time consumed by each activity (Chen and Hsueh, 2008 & Simonson, 1990). The underlying idea of this technique is to locate the project completion path that takes the longest time to complete. The longest path is always the critical path that includes the activities that must be completed for the project to be a success (Badiru, 2012).

Linear Programming was developed in early decades of the twentieth century, but it was only after World WarII that the technique received recognition in academia and business (Hillier and Lieberman, 2010). The technique comes into play whenever a project or a job consists numerous of constraints pertaining to the resources available for completion (Dentzig, 1982). At the same time the objective is to maximize the benefits or minimize the losses. The programming provides a number of solutions to a problem and there is always at least one optimized solution (Rardin, 1998 & Taha, 2007).

Since the degree plan for a MBA includes courses that require pre-requisites (takes precedence), and has the time required to complete each course, CPM appears to be an appropriate technique for drawing the flow diagram for the problem. Linear programming is applicable in the problem since we need to find the longest path (or the shortest time to finish) for completion of the degree, this would be the objective function of the formulation. In terms of constraints, the time required for every course, the pre-requisite for most of the courses, and the choice of electives,need to be taken care of.

Thereare number of constraints present in this problem. The completion of pre-requisites (all under-graduate courses) to satisfy the precedence for a number of courses (graduate courses) in the degree plan is the basic constraint in this problem. The constraint of time required to finish each course is 1 semester. The number of courses (or credit hours) available during each semester is another constraint.

Because all courses are not offered every semester, non-enrollment of a course in one semester may result in an unnecessary delay in degree completion. This is true when a student might not enroll in a course in Fall semester which is a pre-requisite for a course in the following Spring semester. Because the student has not enrolled in the particular course, the enrollment of the advanced course would be delayed by two semesters in this case.

4. GENERAL NETWORK DIAGRAM

Based on all the constraints, the following general diagram has been reached upon. The diagram is not comprehensive in the sense that it is a representation of the original number of nodes and arcs with the smaller number of nodes and arcs. The diagram illustrates that a student has three options in terms of selecting a semester for course enrollment. For example, a student can enroll in a course in any of the three semesters: Fall 1; Spring 1; and Fall 2. This is true for every course till the end of the degree. Moreover all the courses follow the basic constraint of precedence activity and the time required to finish which is 1. Certain variables have been defined for the explanation and formulation purposes. The diagram is based on the concept of CPM and the variables are formulated in the LP equation.
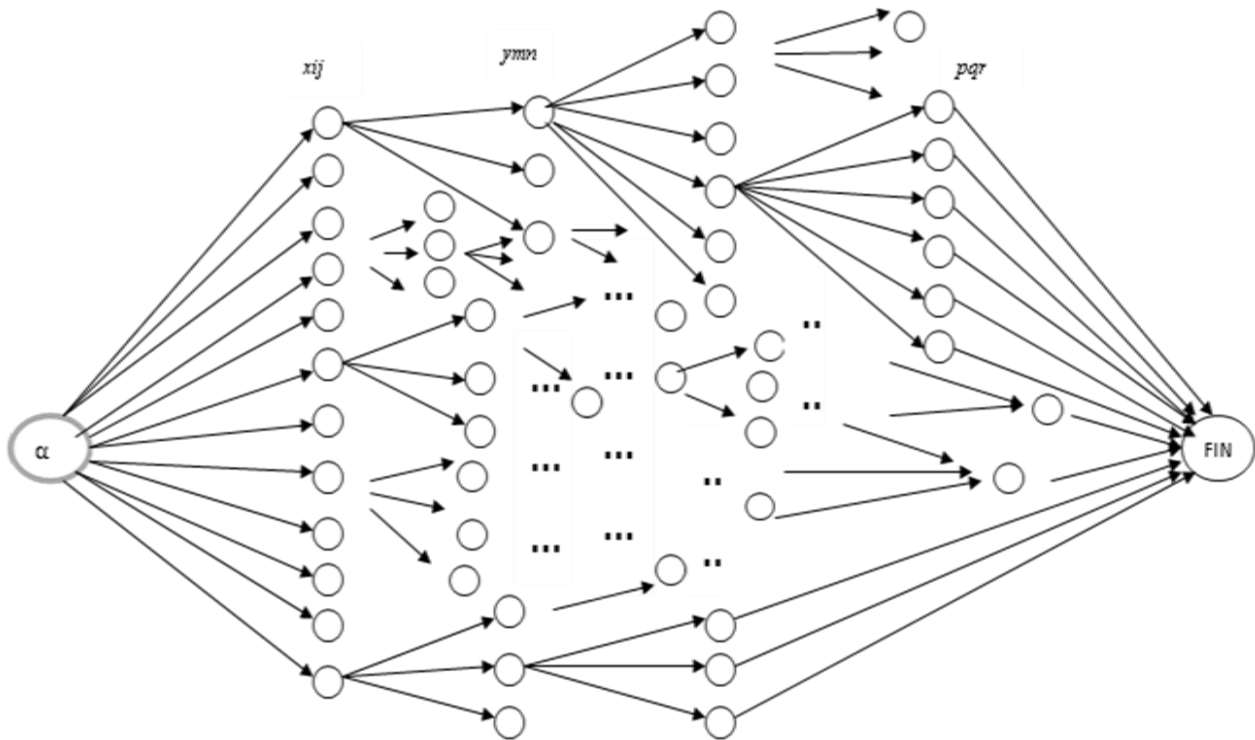
Figure 1: General Diagram

In order to formulate a LP function the following variables have been defined for the general diagram:

- α: the starting node.
- *Fin*: the end (finishing) node.
- λ_h: the duration of the completion of one course on path *h*.
- *ymn*: the course code *y* taken during semester *mn*. For example, *AF1* = course *A* taken in the first Fall semester.
- *xij*: the course *x* taken during semester *ij*. Also, it indicates the nodes located before *ymn*.
- *pqr*: the course *p* taken during semester *qr*. Also, it indicates the nodes located after *ymn*.
- *xijymn*, *ymnpqr*: binary variables. If the path from *xij* to *ymn* or from *ymn* to *pqr* is selected the value is 1 otherwise 0.

The *xij* variable, for the formulation purposes, also represents the courses initiating from the starting node. This means that all initial *xij* courses do not require any pre-requisite.

Figure 1 has been formulated as the following Linear Programming equation with the objective function of maximizing the time required and all the relevant constraints of pre-requisites, time required and choice of electives. The objective function can be expressed as equation (1):

$$MAX \quad \sum_h \sum_x \sum_i \sum_j \sum_y \sum_m \sum_n \lambda_h xijymn \quad (1)$$

The objective function illustrates the summation of all the arcs (routes) between the nodesmultiplied by the time required for completion of each activity which is represented by λ_h.

The objective should satisfy the following constraints:
For the origin node, the equation (2) is:

$$MAX \quad \sum_x \sum_i \sum_j \alpha xij = 1$$

$$(2)$$

This constraint represents the summation of all thearcs (routes) originating from the start node. All these routes must equal one, because any of the arcs (routes) can be on the critical path.

For intermediate nodes, equation (3) is:

$$\sum_x \sum_i \sum_j \sum_y \sum_m \sum_n xijymn = \sum_y \sum_m \sum_n \sum_p \sum_q \sum_r ymnpqr$$

$$(3)$$

For the intermediate nodes, all the incoming arcs to a node must equalize all the outgoing arcs from the same node. The above constraint, according to our variable definitions, represents that all the nodes coming from *xij* nodes to the *ymn* nodes are equal to all the nodes going out from *ymn* nodes to the *pqr* nodes. The value assigned to each variable can either be 1 or 0, depending on which particular route lies on the critical path. 1 means that the route is one the critical path and otherwise 0.

5. PROBLEM SCOPE AND ASSUMPTIONS

The solution to the problem would be optimized in terms of time taken to complete MBA course work. A generalized degree plan would enable the graduate students in the field of business to have an idea about the critical courses that they should take each semester, in order not to delay their degree unnecessarily. For students having special interests in a particular field of study, some extra stem courses (pre-requisites) need to be taken. This would change the critical path identified for a more generalized degree.

However, the vast number of constraints and variables make it very difficult to solve this problem in terms of real numbers. So for simplification purposes, following assumptions have been made to limit the number of constraints and variables in order to generate a solution in terms of actual results:

- The degree starts from the Fall semester.
- No enrollment in the courses offered during Summer semester.
- There is no preference for a particular area of concentration of elective courses. This means that a student take only those elective courses which do not require any further pre-requisites in addition to the basic pre-requisites for the degree.
- A student takes elective courses which I have taken for my degree.
- A student enrolls in 5 courses each semester until the last semester in which the enrollment is based on the number of courses left for the completion of the degree.
- A student enrolls in the courses offered each semester regardless of any class timings during a day and the class days during a week for any or all courses.
- Student scores passing grade in all the courses in the first attempt and do not drop out of courses before its successful completion.

6. SIMPLIFIED DIAGRAM

The simplification assumptions allow us to draw a simplified diagram with actual courses based on the conceptual CPM. The following is a simplified diagram (Figure 2) illustrating what courses a student needs to take in each semester in order to complete the degree as soon as possible.
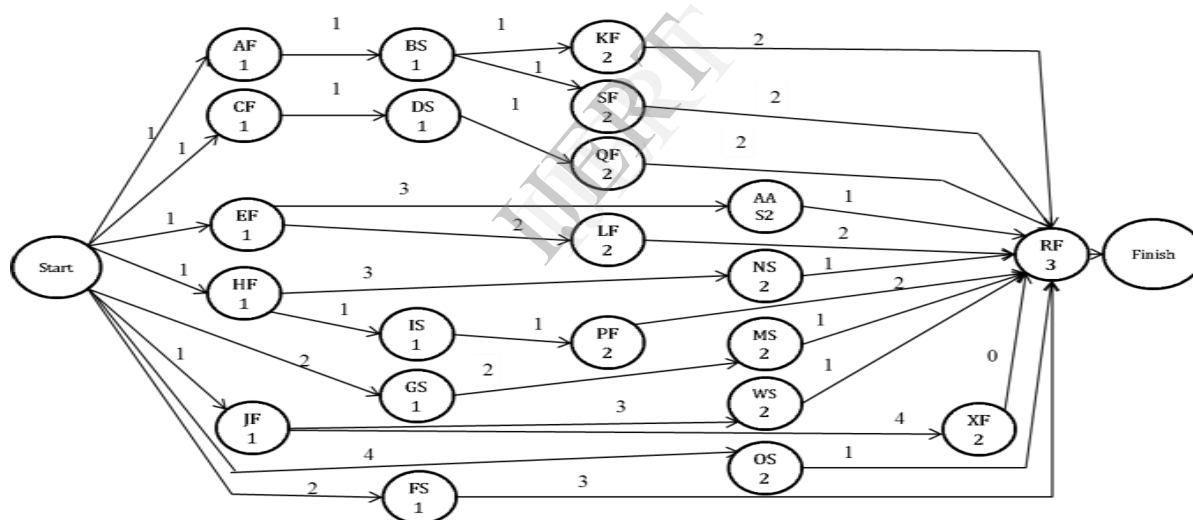

Figure 2: Simplified Diagram

In this diagram, the variables are actual courses taken during different semesters. For example, AF1 in the top first node stands for course coded as A taken during semester Fall of the first year of enrollment. Similarly, all the different nodes have different courses in 5 different semesters: F1 (Fall of year 1); S1 (Spring of year 1); F2 (Fall of year 2); S2 (Spring of year 2); and finally F3 (Fall of year 3). The nodes have been adjusted in the diagram according to their occurrence during the 5 semesters starting from the Fall of year 1.

The time required on each arc describes how long a student has to wait after a particular course has been completed. For example, after completing EF1 (MKTG 3361 in Fall of year 1) a student has to wait 2 semesters for enrolling in LF2 (MKTG 5361 in Fall of year 2). The first reason is the precedence relationship between the two courses i.e. MKTG 5361 cannot be taken unless MKTG 3361 is completed. The second reason is that MKTG 5361 is a Fall only course. So a student has to wait until next Fall when this course would be offered for enrollment. Similar precedence activity relationship, semester offered constraint, and the maximum of 5 courses taken during each semester, explain the time required to complete a course after every course.

7. PROBLEM FORMULATION

The simplified diagram has been formulated as the Linear Programming equation as the following objective function of maximizing the time taken with all the relevant constraints of precedence and time required for each activity. The objective function is:

MAX
aAF1+aCF1+aEF1+aHF1+2aGS1+aJF1+4aOS2+ 2aFS1+AF1BS1+CF1DS1+3EF1AAS2+2EF1LF2 +3HF1NS2+HF1IS1+3FS1RF3+2GS1MS2+3JF1 WS2+4JF1XF3+OS2RF3+BS1KF2+BS1SF2+2K F2RF3+2SF2RF3+DS1QF2+2QF2RF3+AAS2RF 3+2LF2RF3+NS2RF3+IS1PF2+2PF2RF3+MS2R F3+WS2RF3+0XF3RF3

The objective function is the summation of all the arcs (routes) between the nodes multiplied by the time required on each arc.

The constraints can be expressed as following:

aAF1+aCF1+aEF1+aHF1+aGS1+aJF1+aOS2+aFS1=1
AF1BS1-aAF1=0
CF1DS1-aCF1=0
EF1AAS2+EF1LF2-aEF1=0
HF1NS2+HF1IS1-aHF1=0
FS1RF3-aFS1=0
GS1MS2-aGS1=0
JF1WS2+JF1XF3-aJF1=0
OS2RF3-aOS2=0

BS1KF2+BS1SF2-AF1BS1=0
KF2RF3-BS1KF2=0
SF2RF3-BS1SF2=0
DS1QF2-CF1DS1=0
QF2RF3-DS1QF2=0
AAS2RF3-EF1AAS2=0
LF2RF3-EF1LF2=0
NS2RF3-HF1NS2=0
IS1PF2-HF1IS1=0
PF2RF3-IS1PF2=0
MS2RF3-GS1MS2=0
WS2RF3-JF1WS2=0
XF3RF3-JF1XF3=0

The constraints are based on the idea that the entire initial arcs (routes) originating from the start node must equal 1. And all the other arcs (routes) are binary variables; this means that if a particular arc lies on the critical path then its value is one otherwise 0.

The problem can be solved either manually or by specialized software. This formulation has been solved using LINDO®. By typing the objective function and all the relevant constraints the software automatically generates an optimal solution.

8. RESULTS

The solution generated by LINDO® suggests the objective value of 5 which means that at least 5 semesters are required for the successful completion of the MBA degree for a student with non-business background. The following table (Table 2) summarizes the courses taken during each of the 5 semesters in the order of their occurrence.

Table 2: Results

Semester→ Courses↓	Fall 1	Spring 1	Fall 2	Spring 2	Fall 3
	ACCT 2301	ACCT 2302	ACCT 5307	FINC 5331	CISA 5330
	ECON 2301	ECON 2302	ACCT 5311	MGMT 5337	MGMT 5335
	MKTG 3361	BLAW 3341	ECON 5329	MKTG 5363	
	BUAD 3355	FINC 3337	MKTG 5361	MGMT 5322	
	CISA 1301	MGMT 3321	MGMT 5325	CISA 5320	

The above schedule of courses is very critical in terms of timely completion of the degree in 5 semesters. For example, if a student does not enroll in ACCT 2301 in Fall 1 and enrolls in any of the other stem course that does not require pre-requisite then ACCT 2302 cannot be taken in Spring 1. In this case both these courses would be delayed by 1 semester.

Hence ACCT 2301 would be taken in Spring 1 and ACCT 2301 would be taken in Fall 2. This would upset the whole degree plan because both ACCT 5307 and ACCT 5311 which were to be taken in Fall 2 cannot be taken in this semester because both of them have the precedence activity of ACCT 2302. Moreover both are Fall only courses; this means that both would not be offered for enrollment until Fall 3. This in turn would end up into 4 courses in the last semester which is highly non-recommended because of the enrollment in MGMT 5335 (Graduate Research Project) in the last semester. Similarly if student does not follow the schedule of courses for some of the other stem courses, the optimal time of 5 semesters may not hold true and the student might have to spend more time in college for the successful completion of the degree.

9. CONCLUSIONS AND FUTURE STUDY

Based on the solution to the problem and implementation of quantitative analysis techniques, the critical path for the degree plan has been identified for the simplified problem.The CPM and LP techniques have proved to be efficient for application to the problem with time constraints and precedence activities.The problem was simplified with no summer courses taken, 5 courses per semester, limited electives etc.However we may have more options; 3 (or 4) courses limit per semester, some courses can be taken during summer, student's choice in having concentration in a particular field for elective courses.With more constraints and variables, CPM network diagram will be more complex. The diagram and formulation of more flexible problem is not impossible and there are no technical difficulties to solve the problem.However, this task isextremely time consuming and tedious.

In fact, the formulation of a comprehensive and more flexible problem with no artificial assumptions is the idea for future study after for this paper. The comprehensive problem, when formulated and solved, would have different critical paths based on different choices: number of courses enrolled in each semester; enrollment in summer semesters; choice of particular electives etc.

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