

NETWORK PLANNING & THE CHE CURRICULUM

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FOR MANY YEARS now industry has found the Critical Path Method (CPM) to be a considerable aid in planning and scheduling activities. This method determines the shortest period of time required for the completion of a system of activities in the following manner. Each activity is listed with (1) its activity number, (2) its time required for completion (activity duration), (3) those activities which must be completed before starting the activity in question (preceding activities), (4) those activities which cannot be started before the completion of the activity in question (succeeding activities), and (5) any other constraints which are found necessary to be placed on the particular activity, e.g., activity start or finish times.

Once the activities have been listed with this information, the activities may be graphed by activity as in Figure 1 wherein the ordinate has some arbitrary units of time. Those activities having no preceding activities are listed by activity number at the extreme left and the succeeding activities are placed on the graph further to the right according to the time scale. Preceding and succeeding activities are connected with lines to show their relationships with other activities. The time element should never be forgotten with respect to activity duration and specified activity start or finish times.

Once all of the activities have been included on this graph, the activity finding itself to the extreme right is the last activity in a series of activities which define the critical path. The remaining critical path activities can be found by following the lines connecting activity to activity which exhibit no time lag (slack) from the finish of one activity to the start of the next. When this procedure has been completed, the critical path has been defined. If the system of activities is to be completed in the shortest possible time, these critical path activities must be completed in a continuous manner, one right after another with no interruption.

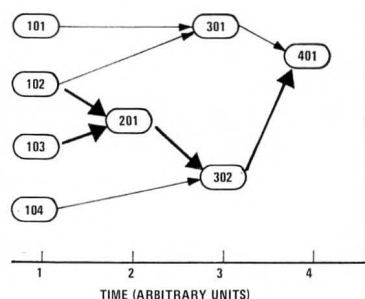
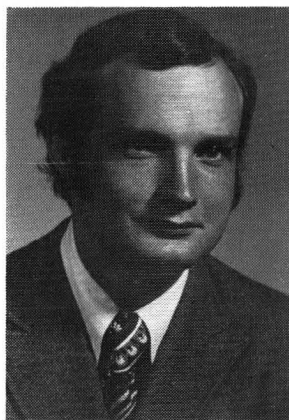


Fig. 1. Sketch of a CPM diagram. Critical path activities (101, 102, 201, 302, 401) are connected by heavy lines.

Now that the critical path has been delineated all the activities can be listed with their earliest start times, latest finish times and slacks such that there will be no increase in the critical path and therefore no increase in the time necessary to complete the entire system of activities. This list of earliest start times, latest finish times and slack offers a framework around which a schedule can be built.

With the advent of computers, programs have been written which can aid in scheduling a system of activities by using CPM. The necessary information is the same as that which is required to complete the CPM diagram as described above, but the time and effort required to obtain the necessary earliest start time and latest finish time for each activity is greatly reduced.

NOW THAT THE GROUND WORK has been laid, it is time to introduce the primary purpose of this article, namely, CPM as an aid in formulating curricula. The question might be asked why such a method is necessary; it can be seen today that universities are changing their curricula at an ever increasing rate, and at the same time complexities are being introduced when departments offer new options to better meet the personal needs and desires of individual students. Keeping this in mind, a tool such as CPM could greatly alleviate much of the toil involved with adapting curricula.

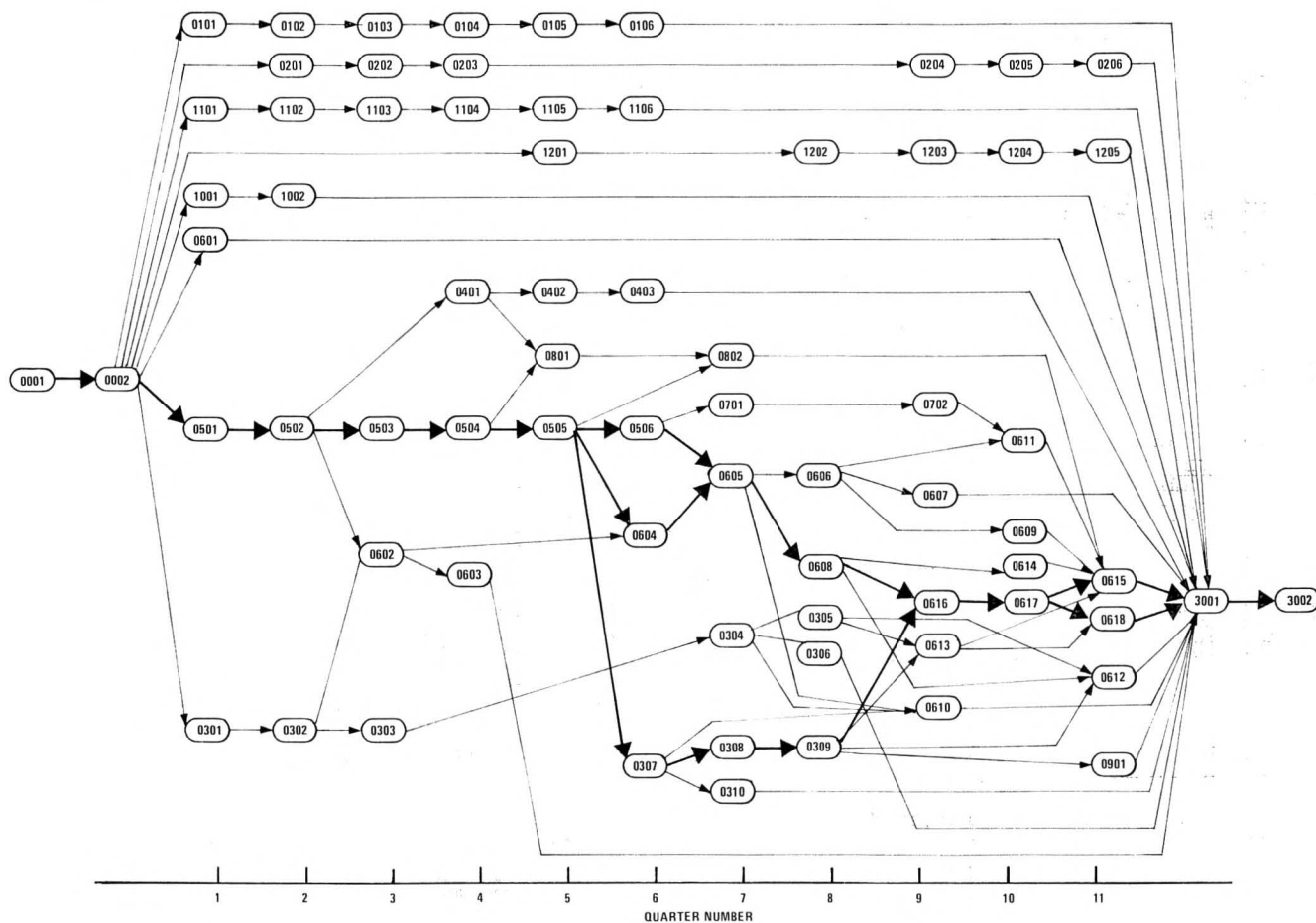


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The method for reducing curriculum information as it appears in a university catalog so that it can be accepted by a CPM computer program is quite easy. The individual courses are assigned activity numbers by which the computer can recognize them. An activity duration whether on a semester, quarter or any other time basis is given to each course. The prerequisite courses fill the

preceding activities category and the courses for which this particular course is a prerequisite fall into the succeeding activities category. If a certain course is required to be taken in a specified year of study or before a specified time in a program of study, the constraints can be accepted by the CPM program by listing a start time or finish time for that course.



With this information the CPM program determines an earliest start time, latest finish time and slack for each course in the particular curriculum. All of the courses which comprise the critical path are fixed as to when they must be

The CPM diagram is helpful in testing time feasibility of proposed curricula and in offering a model which can answer some of the questions dealing with curricula practicality.

Table I. Accelerated Chemical Engineering Curriculum (Eleven Quarters).

Qtr. No.	Activity No.	Course Name	Cr. Hrs.	Prereq. Activities	Earliest Start	Latest Start	Slack
1	501	Calculus I	5	-	1	1	0
1	301	General Chemistry I	5	-	1	3	2
1	101	Humanities I	3	-	1	6	5
1	1101	Physical Training I	1	-	1	6	5
1	1001	Eng. Graphics I	3	-	1	10	9
1	601	Chem. Eng. Orientation	1	-	1	11	10
			18				
2	502	Calculus II	5	501	2	2	0
2	302	General Chemistry II	5	301	2	4	2
2	201	Social Science I	3	-	1	6	5
2	102	Humanities II	3	101	2	7	5
2	1102	Physical Training II	1	1101	2	7	5
2	1002	Eng. Graphics II	3	1001	2	11	9
			20				
3	503	Calculus III	5	502	3	3	0
3	303	General Chemistry III	4	302	3	5	2
3	602	Material Balances	3	302,502	3	5	2
3	202	Social Science II	3	201	2	7	5
3	103	Humanities III	3	102	3	8	5
3	1103	Physical Training III	1	1102	3	8	5
			19				
4	504	Calculus IV	5	503	4	4	0
4	401	Physics I	5	502	3	4	1
4	603	Energy Balances	3	602	4	11	7
4	203	Social Science III	3	202	3	8	5
4	104	Humanities IV	3	103	4	9	5
4	1104	Physical Training IV	1	1103	4	9	5
			20				
5	505	Calculus V	5	504	5	5	0
5	402	Physics II	5	401	4	5	1
5	801	Statics	3	401,504	5	9	4
5	1201	Elective I	3	-	1	7	6
5	105	Humanities V	3	104	5	10	5
5	1105	Physical Training V	1	1104	5	10	5
			20				
6	506	Differential Equations	5	505	6	6	0
6	307	Physical Chemistry I	3	303,402,505	6	6	0
6	604	Computers in Chem. Eng.	3	505,602	6	6	0
6	403	Physics III	5	402	5	11	6
6	106	Humanities VI	3	105	6	11	5
6	1106	Physical Training VI	1	1105	6	11	5
			20				
7	310	Physical Chemistry Lab.	2	307	7	11	4
7	308	Physical Chemistry II	3	307	7	7	0
7	605	Transport Phenomena I	4	506,604	7	7	0
7	304	Organic Chemistry I	3	303	4	8	4
7	701	Electric Fields-Circuits	3	402,506	7	8	1
7	802	Material Science	3	505,801	6	10	4
			18				
8	309	Physical Chemistry III	3	308	8	8	0
8	608	Stagewise Operations	4	605	8	8	0
8	606	Transport Phenomena II	4	605	8	9	1
8	305	Organic Chemistry II	3	304	5	9	4
8	306	Organic Chemistry Lab	2	304	5	11	6
8	1202	Elective II	3	1201	2	8	6
			19				
9	616	Thermodynamics I	3	309,608	9	9	0
9	607	Momentum-Heat Transfer	3	606	9	11	2
9	613	Chemical Kinetics	3	305,309,608	9	10	1
9	610	Chem. Eng. Literature	1	304,307,605	8	11	3
9	702	Elem. Electronics	3	701	8	9	1
9	1203	Elective III	3	1202	3	9	6
9	204	Social Science IV	3	203	4	9	5
			19				
10	617	Thermodynamics II	3	616	10	10	0
10	614	Chem. Eng. Economics	3	608	9	10	1
10	611	Process Instrumentation	3	606,702	9	10	1
10	609	Mass Transfer	4	606	9	10	1
10	1204	Elective IV	3	1203	4	10	6
10	205	Social Science V	3	204	5	10	5
			19				
11	618	Comprehensive Prob.	3	613,614,617	11	11	0
11	615	Chemical Plant Design	3	609,611,613	11	11	0
				614,617,802			
11	612	Polymer Science	3	305,309,608	9	11	2
11	901	General Metallurgy	3	309	9	11	2
11	1205	Elective V	3	1204	5	11	6
11	206	Social Science VI	3	205	6	11	5
			18				

Table II. Typical Chemical Engineering Curriculum (Twelve Quarters).

Qtr. No.	Activity No.	Course Name	Cr. Hrs.	Prereq. Activities	Earliest Start	Latest Start	Slack
1	501	Calculus I	5	-	1	2	1
1	301	General Chemistry I	5	-	1	4	3
1	101	Humanities I	3	-	1	7	6
1	1101	Physical Training I	1	-	1	7	6
1	601	Chem. Eng. Orientation	1	-	1	12	11
1	1201	Elective I	3	-	1	8	7
			18				
2	502	Calculus II	5	501	2	3	1
2	302	General Chemistry II	5	301	2	5	3
2	102	Humanities II	3	101	2	8	6
2	1001	Eng. Graphics I	3	-	1	11	10
2	1102	Physical Training II	1	1101	2	8	6
			17				
3	503	Calculus III	5	502	3	4	1
3	303	General Chemistry III	4	302	3	6	3
3	103	Humanities III	3	102	3	9	6
3	1002	Eng. Graphics II	3	1001	2	12	10
3	1103	Physical Training III	1	1102	3	9	6
3	1202	Elective II	3	1201	2	9	7
			19				
4	504	Calculus IV	5	503	4	5	1
4	401	Physics I	5	502	3	5	2
4	602	Material Balances	3	302,502	3	6	3
4	104	Humanities IV	3	103	4	10	6
4	1104	Physical Training IV	1	1103	4	10	6
			17				
5	505	Calculus V	5	504	5	6	1
5	402	Physics II	5	401	4	6	2
5	603	Energy Balances	3	602	4	12	8
5	105	Humanities V	3	104	5	11	6
5	1105	Physical Training V	1	1104	5	11	6
			17				
6	506	Differential Equations	5	505	6	7	1
6	403	Physics III	5	502	5	12	7
6	604	Computers in Chem. Eng.	3	505,602	6	7	1
6	106	Humanities VI	3	105	6	12	6
6	1106	Physical Training VI	1	1105	6	12	6
			17				
7	605	Transport Phenomena I	4	506,604	7	8	1
7	304	Organic Chemistry I	3	303	4	9	5
7	307	Physical Chemistry I	3	303,402,505	6	7	1
7	801	Statics	3	401,504	5	10	5
7	201	Social Science I	3	-	1	7	6
7	1203	Electives III	3	1202	3	10	7
			19				
8	606	Transport Phenomena II	4	605	8	10	2
8	305	Organic Chemistry II	3	304	5	10	5
8	308	Physical Chemistry II	3	307	7	8	1
8	310	Physical Chemistry Lab	2	307	7	12	5
8	802	Material Science	3	505,801	6	11	5
8	202	Social Science II	3	201	2	8	6
			18				
9	607	Momentum-Heat Transfer	3	606	9	12	3
9	608	Stagewise Operations	4	605	8	9	1
9	306	Organic Chemistry Lab	2	304	5	12	7
9	309	Physical Chemistry III	3	308	8	9	1
9	203	Social Science III	3	202	3	9	6
9	701	Elec. Fields Circuits	3	402,506	7	9	2
			18				
10	616	Thermodynamics I	3	309,608	9	10	1
10	612	Polymer Science	3	305,309,608	9	12	3
10	609	Mass Transfer	3	606	9	11	2
10	610	Chem. Eng. Literature	1	304,307,605	8	12	4
10	702	Elem. Electronics	3	701	8	10	2
10	204	Social Science IV	3	203	4	10	6
			17				
11	617	Thermodynamics II	3	616	10	11	1
11	613	Chemical Kinetics	3	305,309,608	9	11	2
11	611	Process Instrumentation	3	606,702	9	11	2
11	614	Chem. Eng. Economics	3	608	9	11	2
11	1204	Elective IV	3	1203	4	11	7
11	205	Social Science V	3	204	5	11	6
			18				
12	618	Comprehensive Prob.	3	613,614,617	11	12	1
				609,611,613			
12	615	Chemical Plant Design	3	614,616,802	11	12	1
12	901	General Metallurgy	3	309	9	12	3
12	206	Social Science VI	3	205	6	12	6
12	1205	Elective V	3	1204	5	12	7
			15				

started or completed; however, the remainder of the courses can be taken at any time within the constraints of the earliest start and latest finish times. In order to assist in selecting definite start dates for these courses which are not part of the critical path, various programs, e.g., RAMPS (Resource Allocation and Multiple Project Scheduling)*, can be used to devise the final schedule. These programs distribute the various courses within the limits of their earliest start and latest finish times such that there will be a nearly constant number of credit hours per school term throughout the entire program of study.

A typical undergraduate chemical engineering curriculum is used as an example to illustrate the concept of CPM as a scheduling aid. Figure 2 is a CPM diagram of this curriculum wherein the activity numbers represent various courses (the two activities at the extreme left and the two activities at the extreme right, 0001, 0002, and 3002, are dummy activities and are included only to facilitate the operation of the particular CPM program which was used). This figure illustrates the role prerequisites play in scheduling courses.

Table I shows the final schedule which was derived from the CPM program. The earliest start times, latest finish times and slacks were provided by the CPM program enabling the critical path to be defined and also giving the shortest time for completion of the entire program of study. The courses which do not lie on the critical path and are accompanied by slacks were distributed manually, and the final product is a schedule which breaks the individual courses down into school quarters.

The actual schedule for this curriculum as it might have appeared in a university catalog is listed in Table II and consists of twelve quarters. The information obtained from the CPM program showed that the curriculum could be completed in an accelerated program of eleven quarters in which no more than 20 credit hours are required per quarter.

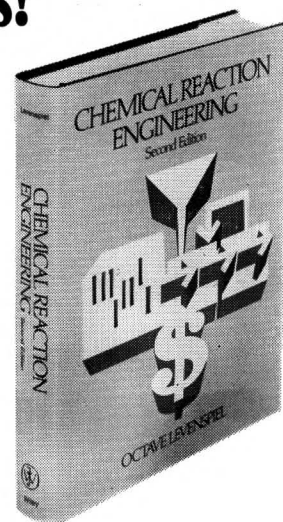
Referring once again to Figure 2 it is seen that the courses have been distributed among the eleven quarters of the accelerated program as they appear in Table I. This type of CPM diagram can be helpful not only in testing feasibility of the time considerations of proposed curricula but also in offering a model which can answer some of the questions dealing with curricula practicality. □

*Kurzeja, J. T., *Hydrocarbon Processing*, April, 1965, p. 171.

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