AC 2008-1523: DEVELOPMENT OF AN AD-HOC CURRICULUM ADVISING TOOL TO IMPROVE STUDENT PROGRESS USING CPM AND PERT ANALYSIS

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Development of an Ad-hoc Curriculum Advising Tool to Improve Student Progress Using CPM and PERT Analysis

Abstract

The paper demonstrates the application of two project management tools designed to help the students complete their curriculum sooner. The first tool provides a visualization map of course sequences, customized for each student, making advising adjustments that will optimize the time to obtain the degree under a constrained set of resources. The second tool collects information from multiple students through several semesters and can be used to identify bottlenecks in the curriculum using probability distributions for the time to finish the program.

Students that attend commuter campuses many times suffer delays in the completion of their courses due to an inadequate selection of classes each semester. In addition those students can't take the ideal workload because of other external factors. Therefore the use of their time and resources has to be optimized to decrease the time needed to obtain their degree. The advising process could be enhanced by modeling academic programs as complex projects that require constant management to be completed on time. The methodology is inspired by the use of project management (PM) tools from operations research.

A complex project requires two phases, planning and execution. The planning phase establishes a series of major tasks and continues breaking them into smaller parts. The next step identifies dependencies among the tasks creating the critical path where the two major constraints are time and resources required. The Critical Path Method (CPM) is used to identify the vital chain of events to finish a project. The Program Evaluation and Review Technique (PERT) were developed to expand CPM capabilities. The innovation included a probabilistic model using best, worst, and expected times to complete each task. Therefore, PERT produces an estimated completion time of the project, within a probability distribution.

The execution phase of project management monitors the progress of each task and the use of resources. The art of project management consists of the reassignment of resources when the events deviate from the original plan. Historical data collected in this process is used in future cycles to generate better plans.

The critical path and time required to finish the program curriculum can be estimated using the CPM and PERT methods. Students will be advised better to allocate limited resources and finish the program in the shortest time possible. The application of operations research techniques to student achievement records will provide information that becomes a series of longitudinal descriptors that permit the evaluation of the program curriculum and help its improvement.

Introduction

The progression of a student through an academic degree plan can be viewed as a big project with time and resource constraints. The two major objectives are finishing the program in the shortest possible time and with the fewest resources. For each individual student the tools will assist in the recommendation of the critical courses to take. The statistics of many students will draw attention to the bottlenecks in the program and allow curriculum improvements.

The planning phase establishes a series of major tasks and continues breaking them into smaller parts. The next step identifies dependencies among the tasks creating the critical path where the two major constraints are time and resources required. For more than half a century, engineers have used the Critical Path Method (CPM) to identify the vital chain of events to finish a project. The critical path is the main sequence in a series of tasks where delays in any of them will holdup the entire project. For example the critical sequence is identified for a set of several courses in Figure 1, with the required times for completion and the PERT times.

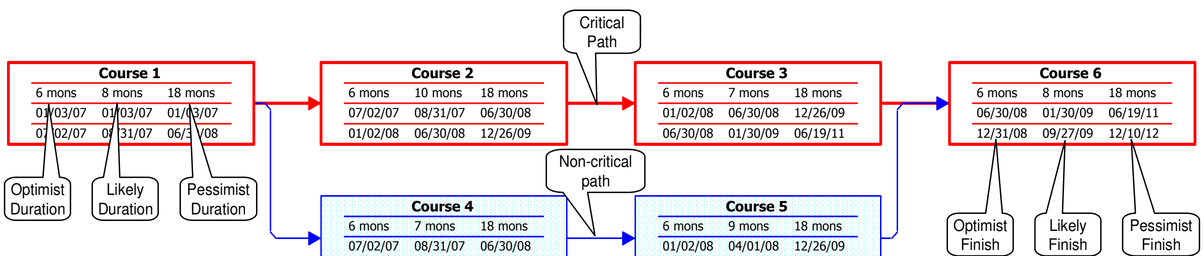


Figure 1, PERT Time Completion Estimates

ID	Task Name	Opt Dur	Opt Start	Opt Finish
1	Course 1	6 mons	01/03/07	07/02/07
2	Course 2	6 mons	07/02/07	01/02/08
3	Course 3	6 mons	01/02/08	06/30/08
4	Course 4	6 mons	07/02/07	01/02/08
5	Course 5	6 mons	01/02/08	06/30/08
6	Course 6	6 mons	06/30/08	12/31/08

ID	Task Name	Duration	Start	Finish
1	Course 1	9.33 mons	01/03/07	10/10/07
2	Course 2	10.67 mons	10/10/07	08/29/08
3	Course 3	8.67 mons	08/29/08	05/20/09
4	Course 4	8.67 mons	10/10/07	06/30/08
5	Course 5	10 mons	06/30/08	04/30/09
6	Course 6	9.33 mons	05/20/09	02/24/10

ID	Task Name	Pes Dur	Pes Start	Pes Finish
1	Course 1	18 mons	01/03/07	06/30/08
2	Course 2	18 mons	06/30/08	12/26/09
3	Course 3	18 mons	12/26/09	06/19/11
4	Course 4	18 mons	06/30/08	12/26/09
5	Course 5	18 mons	12/26/09	06/19/11
6	Course 6	18 mons	06/19/11	12/10/12

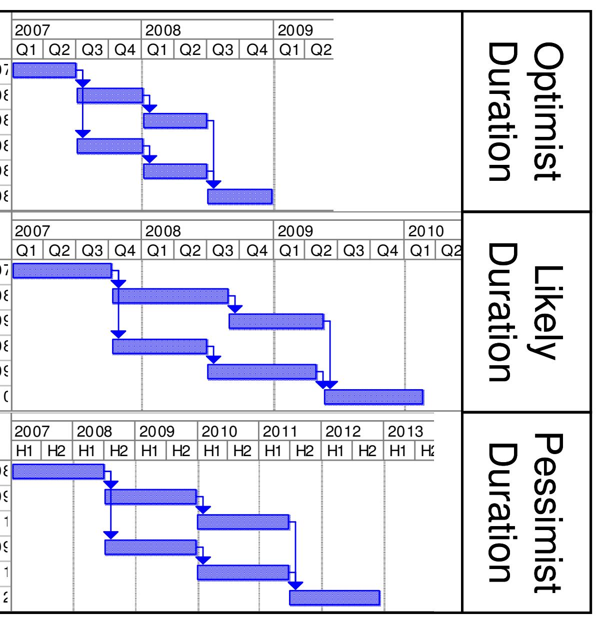


Figure 2, Gantt Charts for Different Estimates

In the late 1950's, the Program Evaluation and Review Technique (PERT) was developed [1] to support large military programs. The innovation included an expanded model using best, worst, and more likely times to complete each task. Therefore, PERT produces an estimated project completion time within a Gamma probability distribution. Although the curriculum might have different tracks (e.g. math and physics) that are designed to converge in a particular semester, the probability that a student will take longer time in one particular track (e.g. math) will be highlighted by the PERT method. Therefore emphasis could be made to reduce the probability of delays along that particular track. In Figure 2 we show the Gantt charts corresponding to the optimist, pessimist and more probable completion times.

The execution phase of project management monitors the progress of each task and the use of resources. The art of project management consists of the reassignment of resources when the events deviate from the original plan. Using the same CPM/PERT tools, the project is updated reflecting the current progress and a decision is made regarding the allocation of resources to those tasks that will produce the shortest time to completion. Finally historical data is collected and used in future cycles to generate better plans.

ID	Task Name	Start	Finish	Resource Name
1	Course 1 (3Cr)	Mon 01/01	Mon 10/08	Credit 2[300%]
2	Course 2 (3Cr)	Mon 10/08	Wed 08/27	Credit 2[300%]
3	Course 3 (3Cr)	Wed 08/27	Mon 05/18	Credit 2[300%]
4	Course 4 (4Cr)	Mon 10/08	Sat 06/28	Credit 2[400%]
5	Course 5 (2Cr)	Sat 06/28	Tue 04/28	Credit 2[200%]
6	Course 6 (3Cr)	Mon 05/18	Mon 02/22	Credit 2[300%]

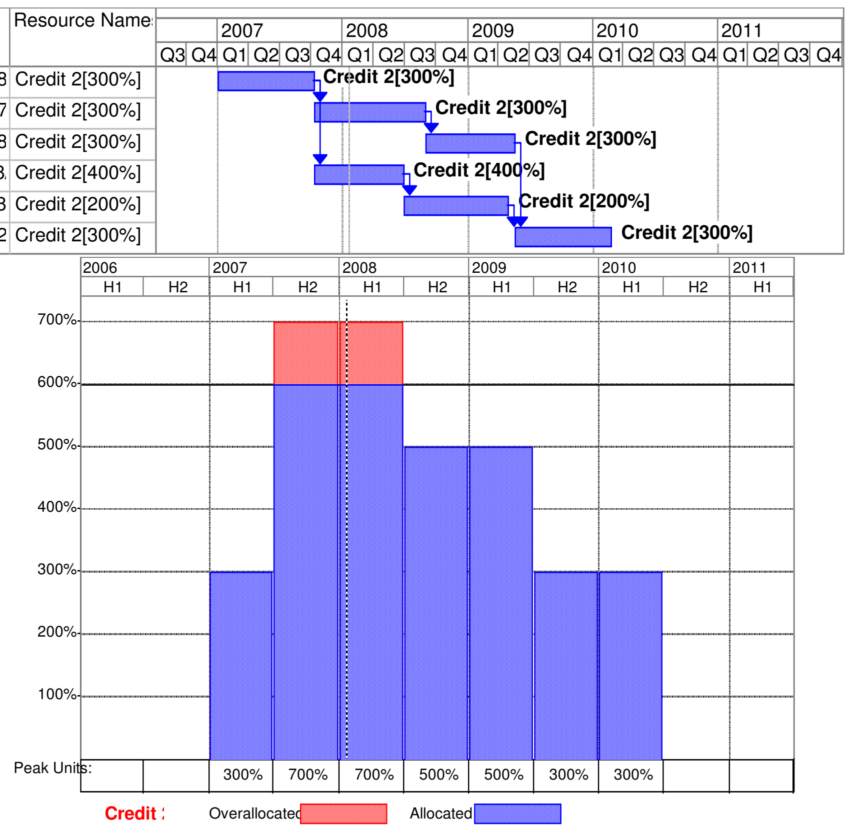
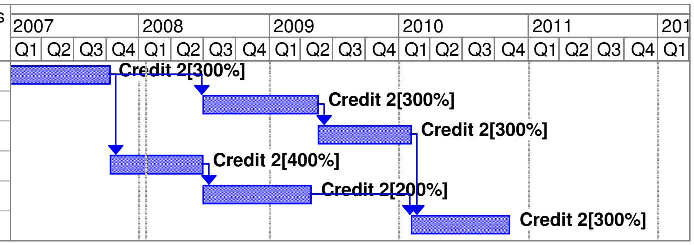


Figure 3, Credits Needed Exceed Available Student Time

For example in Figure 3 we show the Gant Chart and the credits required for a student in a conventional sequence. There is a period of time that the student needs to take 7 credits (700%) but he can only take 6 (600%) due to external reasons. Therefore we need to adjust the sequence to try to finish as early as possible. Then using the project management tools it is possible to level the use of the student time to limit the courses to only 6 credits as illustrated in Figure 4. Notice that 1 Credit = 100% resource consumption for the program representation.

ID	Task Name	Start	Finish	Resource Names
1	Course 1 (3Cr)	Mon 01/01/	Mon 10/08/	Credit 2[300%]
2	Course 2 (3Cr)	Sat 06/28/	Mon 05/18/	Credit 2[300%]
3	Course 3 (3Cr)	Mon 05/18/	Tue 02/02/	Credit 2[300%]
4	Course 4 (4Cr)	Mon 10/08/	Sat 06/28/	Credit 2[400%]
5	Course 5 (2Cr)	Sat 06/28/	Tue 04/28/	Credit 2[200%]
6	Course 6 (3Cr)	Tue 02/02/	Tue 11/09/	Credit 2[300%]



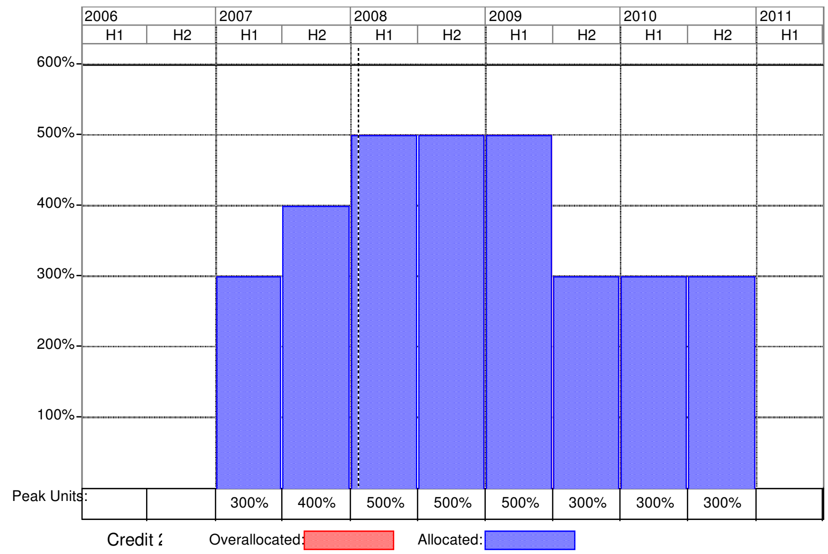


Figure 4, Sequence Adjusted to Match Available Resources

Use of CPM and PERT techniques for the course sequences

The methodology is inspired by the use of project management tools from operations research. The main hypothesis is that a degree plan can be visualized as a complex project and it requires two phases, planning and execution.

The major tasks in a project are equivalent to the courses in the curriculum. Therefore, each student has to administer his own "Educational Career" project with the limited number of credit hours that the student can allocate to school. The traditional layout of courses assumes that a student has completed a course at a satisfactory level before moving into the next, as shown in Figure 2. We want to expand the concept of academic threads [2-4] by linking course dependencies. Instead of considering that they will be completed in a single semester we will include average and pessimist durations. The information obtained by PERT analysis will emphasize courses that could further delay more the time to get a degree. The continuous evaluation of dependencies might be used to bundle some outcomes into different courses and make an integrated curriculum with other programs.

There have been several successful attempts [5-9] to create threads around a single common area, such as a large design project that crosses several courses in their curriculum. In contrast this effort takes all the existing courses and outcomes and relates them in common threads. Other projects attempted to use total quality management (TQM) in educational process[10, 11]; however their focus were oriented toward organization and cultural changes. The extra efforts required to document and manage TQM methods resulted in limited success. Our proposal has a narrower scope using only some project management tools, making it feasible to implement and sustain in the context proposed.

The recommended project management tool is based on templates using commercial PM software, such as Microsoft Project, "Primavera SureTrack", IMSI TurboProject or eProject applications[12]. We employed MS-Project to build our applications due to its availability and advanced characteristics. We created program templates representing an Electrical Engineering Degree Plan. Then we allocated resources representing the number of credits that a student can take and requirements for each class. We still need to collect longitudinal statistics to determine the PERT times for each course.

Results

Example of Course Sequence of a Degree Plan in Electrical Engineering

First we made a representation of an electrical engineering degree plan and converted it into a project with tasks, resources, prerequisites, co-requisites, etc. The first result obtained in the simulation is the critical path. It identified the Mathematics and Physics courses to be a priority because they could delay "Electric Circuits" that is the prerequisite for all Junior EE courses. This can be illustrated in the Network Diagram shown in Figure 5.

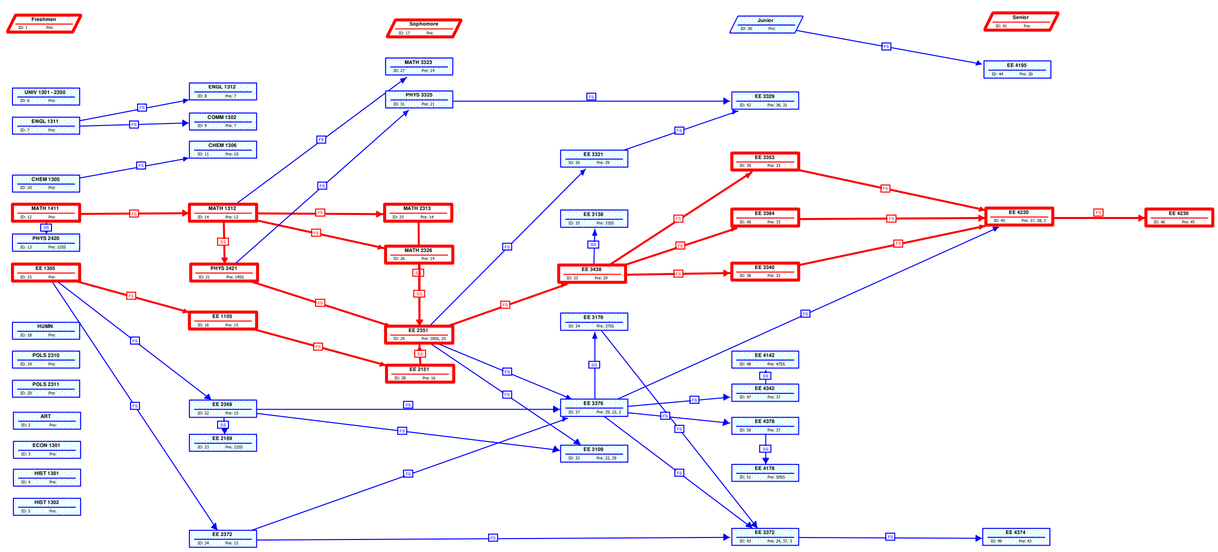


Figure 5, Network Diagram Showing the Critical Path in an EE Degree Plan

The Gant Chart shows the time line in which each course is taken (Figure 6). It demonstrates that under ideal conditions a student might conclude the entire program in seven semesters assuming no restrictions in the total number of courses (or credits) that can be taken concurrently.

ID		Task Name	Predecesso	Duration	Resource Names
1		**Freshmen**		**360 days?**	
2		ART		5.81 mons?	Credit[300%]
3		ECON 1301		5.81 mons?	Credit[300%]
4		HIST 1301		5.81 mons?	Credit[300%]
5		HIST 1302		5.81 mons?	Credit[300%]
6		UNIV 1301 - 2350		5.81 mons?	Credit[300%]
7		ENGL 1311		5.81 mons?	Credit[300%]
8		ENGL 1312	7	5.81 mons?	Credit[300%]
9		COMM 1302	7	5.81 mons?	Credit[300%]
10		CHEM 1305		5.81 mons?	Credit[300%]
11		CHEM 1306	10	5.81 mons?	Credit[300%]
12		MATH 1411		5.81 mons?	Credit[400%]
13		MATH 1312	12	5.81 mons?	Credit[300%]
14		EE 1305/1105		5.81 mons?	Credit[400%]
15		**Sophomore**		**540 days?**	
16		PHYS 2420	12SS	5.81 mons?	Credit[400%]
17		HUMN		5.81 mons?	Credit[300%]
18		POLS 2310		5.81 mons?	Credit[300%]
19		POLS 2311		5.81 mons?	Credit[300%]
20		PHYS 2421	13SS,16	5.81 mons?	Credit[400%]
21		EE 2369 / 2169	14	5.81 mons?	Credit[400%]
22		EE 2372	14	5.81 mons?	Credit[300%]
23		MATH 2313	13	5.81 mons?	Credit[300%]
24		MATH 2326	13	5.81 mons?	Credit[300%]
25		MATH 3323	13	5.81 mons?	Credit[300%]
26		EE 2351 / 2151	23SS,24SS	5.81 mons?	Credit[400%]
27		**Junior**		**540 days?**	
28		PHYS 3325	20	5.81 mons?	Credit[300%]
29		EE 3109	21,26	5.81 mons?	Credit
30		EE 3438 / 3138	26	5.81 mons?	Credit[500%]
31		EE 3321	26	5.81 mons?	Credit[300%]
32		EE 3376 / 3176	26,21,22	5.81 mons?	Credit[400%]
33		EE 3340	30	5.81 mons?	Credit[300%]
34		EE 3353	30	5.81 mons?	Credit[300%]
35		EE 3384	30	5.81 mons?	Credit[300%]
36		**Senior**	**1**	**540 days?**	
37		EE 3329	31,28	5.81 mons?	Credit[300%]
38		EE 3372	22,32	5.81 mons?	Credit[300%]
39		EE 4195	27	5.81 mons?	Credit
40		EE 4220	32,33,34,3	5.81 mons?	Credit[200%]
41		EE 4230	40	5.81 mons?	Credit[200%]
42		EE 4342 / 4142	32	5.81 mons?	Credit[400%]
43		EE 4374	38	5.81 mons?	Credit[300%]
44		EE 4378 / 4178	32	5.81 mons?	Credit[400%]

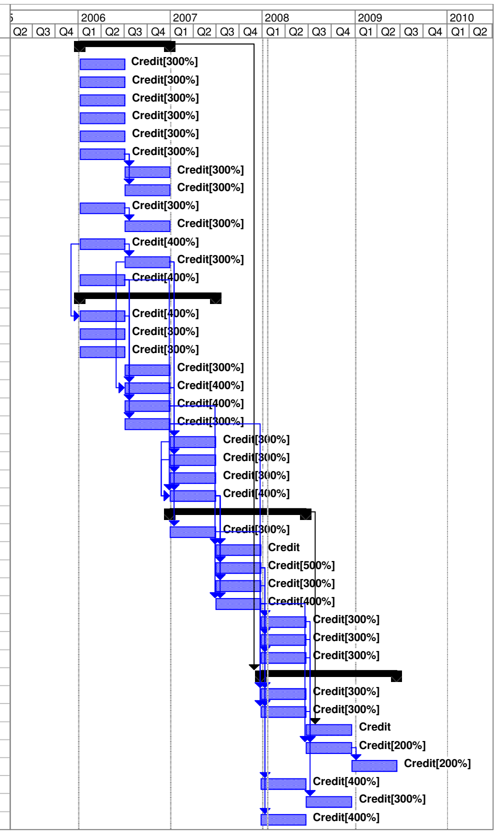


Figure 6, Course Sequence Gant Chart with Unrestricted Credits per Semester

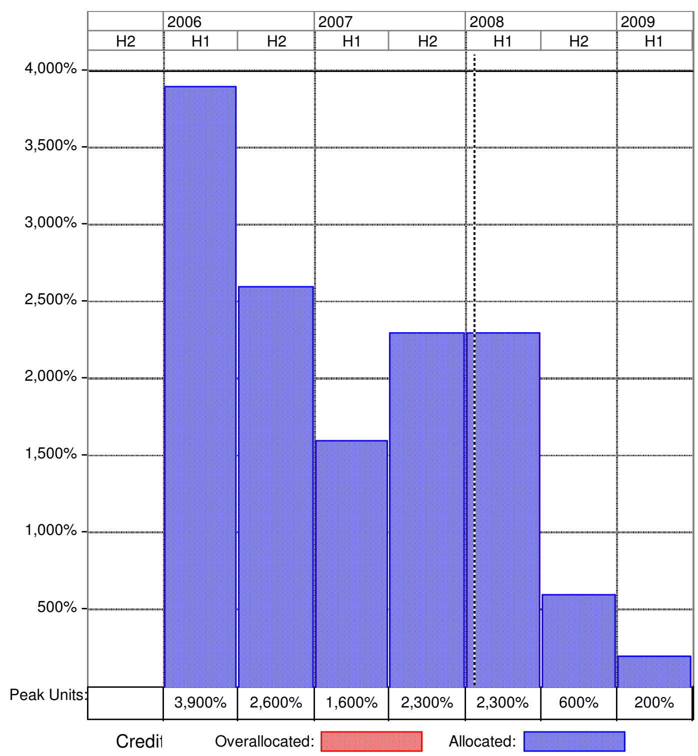


Figure 7, Resources Needed per Period with no Restrictions

However the resource graph (Figure 7) shows that in order to complete the program in such time, the student will need to take 39 credits the first semester, 26 the second, and so on. That is unrealistic and adjustments must be made to consider the allowed number of credits that the student can really take.

Degree Plan in Electrical Engineering restricted to 36 credits per year

A second example illustrates a typical student that takes an average of 36 credits per year or 18 credits per semester. The Gant Chart (Figure 8) shows that the student will need now to take eight semesters of courses but never exceeding a load of more than 18 credits per semester as shown in the resource graph (Figure 9).

ID		Task Name	Predecessc	Duration	Resource Names
1		**Freshmen**		**1080 days?**	
2		ART		5.81 mons?	Credit[300%]
3		ECON 1301		5.81 mons?	Credit[300%]
4		HIST 1301		5.81 mons?	Credit[300%]
5		HIST 1302		5.81 mons?	Credit[300%]
6		UNIV 1301 - 2350		5.81 mons?	Credit[300%]
7		ENGL 1311		5.81 mons?	Credit[300%]
8		ENGL 1312	7	5.81 mons?	Credit[300%]
9		COMM 1302	7	5.81 mons?	Credit[300%]
10		CHEM 1305		5.81 mons?	Credit[300%]
11		CHEM 1306	10	5.81 mons?	Credit[300%]
12		MATH 1411		5.81 mons?	Credit[400%]
13		MATH 1312	12	5.81 mons?	Credit[300%]
14		EE 1305/1105		5.81 mons?	Credit[400%]
15		**Sophomore**		**1080 days?**	
16		PHYS 2420	12SS	5.81 mons?	Credit[400%]
17		HUMN		5.81 mons?	Credit[300%]
18		POLS 2310		5.81 mons?	Credit[300%]
19		POLS 2311		5.81 mons?	Credit[300%]
20		PHYS 2421	13SS,16	5.81 mons?	Credit[400%]
21		EE 2369 / 2169	14	5.81 mons?	Credit[400%]
22		EE 2372	14	5.81 mons?	Credit[300%]
23		MATH 2313	13	5.81 mons?	Credit[300%]
24		MATH 2326	13	5.81 mons?	Credit[300%]
25		MATH 3323	13	5.81 mons?	Credit[300%]
26		EE 2351 / 2151	23SS,24SS	5.81 mons?	Credit[400%]
27		**Junior**		**540 days?**	
28		PHYS 3325	20	5.81 mons?	Credit[300%]
29		EE 3109	21,26	5.81 mons?	Credit
30		EE 3438 / 3138	26	5.81 mons?	Credit[500%]
31		EE 3321	26	5.81 mons?	Credit[300%]
32		EE 3376 / 3176	26,21,22	5.81 mons?	Credit[400%]
33		EE 3340	30	5.81 mons?	Credit[300%]
34		EE 3353	30	5.81 mons?	Credit[300%]
35		EE 3384	30	5.81 mons?	Credit[300%]
36		**Senior**	**1,25**	**360 days?**	
37		EE 3329	31,28	5.81 mons?	Credit[300%]
38		EE 3372	22,32	5.81 mons?	Credit[300%]
39		EE 4195	27	5.81 mons?	Credit
40		EE 4220	32,33,34,35	5.81 mons?	Credit[200%]
41		EE 4230	40	5.81 mons?	Credit[200%]
42		EE 4342 / 4142	32	5.81 mons?	Credit[400%]
43		EE 4374	38	5.81 mons?	Credit[300%]
44		EE 4378 / 4178	32	5.81 mons?	Credit[400%]

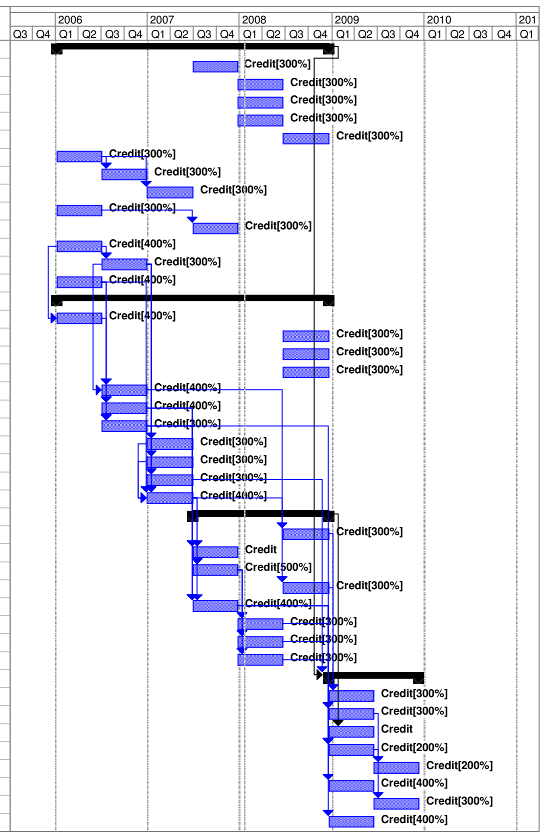


Figure 8, Course Sequence Adjusted to 18 Credits per Semester (36 per year)

This approach just increased one semester for the completion but it allocated the courses in the optimal way maintaining the balance of resource consumption.

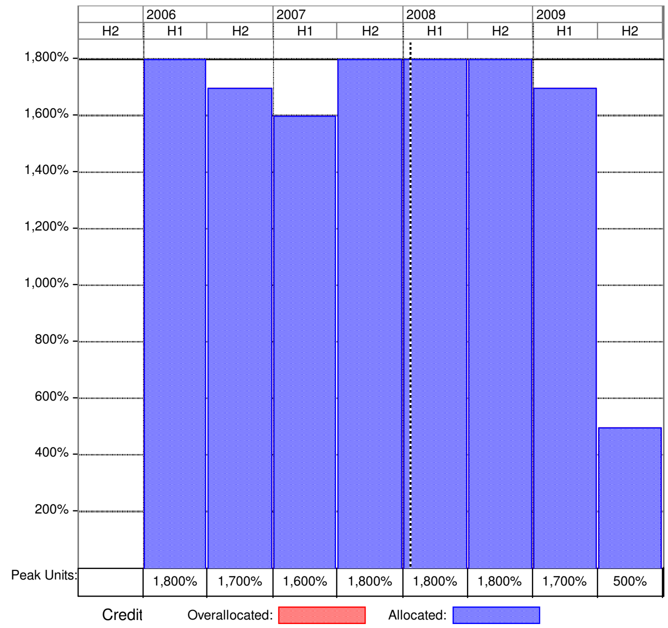
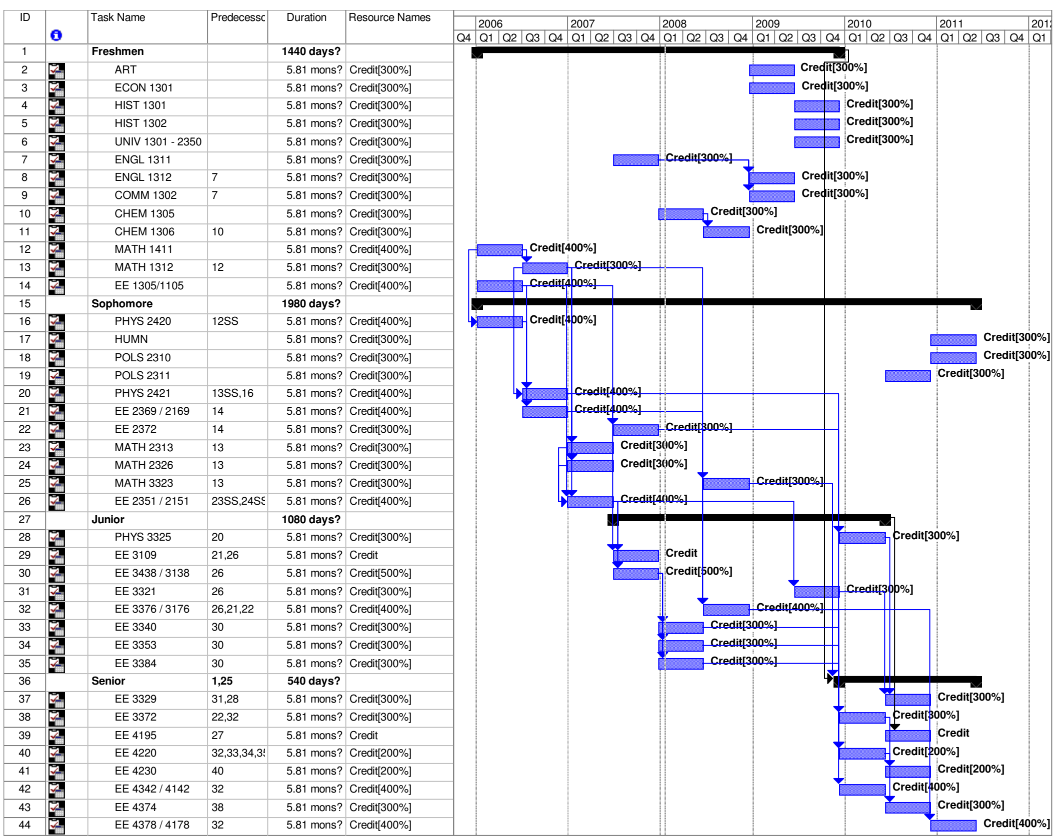


Figure 9, Credits Limited to 18 per Semester

Degree Plan in Electrical Engineering Restricted To 24 Credits per Year



ID		Task Name	Predecesso	Duration	Resource Names
1		**Freshmen**		**1440 days?**	
2		ART		5.81 mons?	Credit[300%]
3		ECON 1301		5.81 mons?	Credit[300%]
4		HIST 1301		5.81 mons?	Credit[300%]
5		HIST 1302		5.81 mons?	Credit[300%]
6		UNIV 1301 - 2350		5.81 mons?	Credit[300%]
7		ENGL 1311		5.81 mons?	Credit[300%]
8		ENGL 1312	7	5.81 mons?	Credit[300%]
9		COMM 1302	7	5.81 mons?	Credit[300%]
10		CHEM 1305		5.81 mons?	Credit[300%]
11		CHEM 1306	10	5.81 mons?	Credit[300%]
12		MATH 1411		5.81 mons?	Credit[400%]
13		MATH 1312	12	5.81 mons?	Credit[300%]
14		EE 1305/1105		5.81 mons?	Credit[400%]
15		**Sophomore**		**1980 days?**	
16		PHYS 2420	12SS	5.81 mons?	Credit[400%]
17		HUMN		5.81 mons?	Credit[300%]
18		POLS 2310		5.81 mons?	Credit[300%]
19		POLS 2311		5.81 mons?	Credit[300%]
20		PHYS 2421	13SS,16	5.81 mons?	Credit[400%]
21		EE 2369 / 2169	14	5.81 mons?	Credit[400%]
22		EE 2372	14	5.81 mons?	Credit[300%]
23		MATH 2313	13	5.81 mons?	Credit[300%]
24		MATH 2326	13	5.81 mons?	Credit[300%]
25		MATH 3323	13	5.81 mons?	Credit[300%]
26		EE 2351 / 2151	23SS,24SS	5.81 mons?	Credit[400%]
27		**Junior**		**1080 days?**	
28		PHYS 3325	20	5.81 mons?	Credit[300%]
29		EE 3109	21,26	5.81 mons?	Credit
30		EE 3438 / 3138	26	5.81 mons?	Credit[500%]
31		EE 3321	26	5.81 mons?	Credit[300%]
32		EE 3376 / 3176	26,21,22	5.81 mons?	Credit[400%]
33		EE 3340	30	5.81 mons?	Credit[300%]
34		EE 3353	30	5.81 mons?	Credit[300%]
35		EE 3384	30	5.81 mons?	Credit[300%]
36		**Senior**	**1,25**	**540 days?**	
37		EE 3329	31,28	5.81 mons?	Credit[300%]
38		EE 3372	22,32	5.81 mons?	Credit[300%]
39		EE 4195	27	5.81 mons?	Credit
40		EE 4220	32,33,34,35	5.81 mons?	Credit[200%]
41		EE 4230	40	5.81 mons?	Credit[200%]
42		EE 4342 / 4142	32	5.81 mons?	Credit[400%]
43		EE 4374	38	5.81 mons?	Credit[300%]
44		EE 4378 / 4178	32	5.81 mons?	Credit[400%]

Figure 10, Course Sequence Limited to only 12 Credits per Semester (24 per year)

As an extreme case we modeled the situation of a student that only takes the minimum load to be considered a full time student (Figure 10). That is 12 credits per semester or 24 credits per year (Figure 11). Under that scenario the system rebalanced the courses to maintain the restriction and the time for completion is extended to eleven semesters.

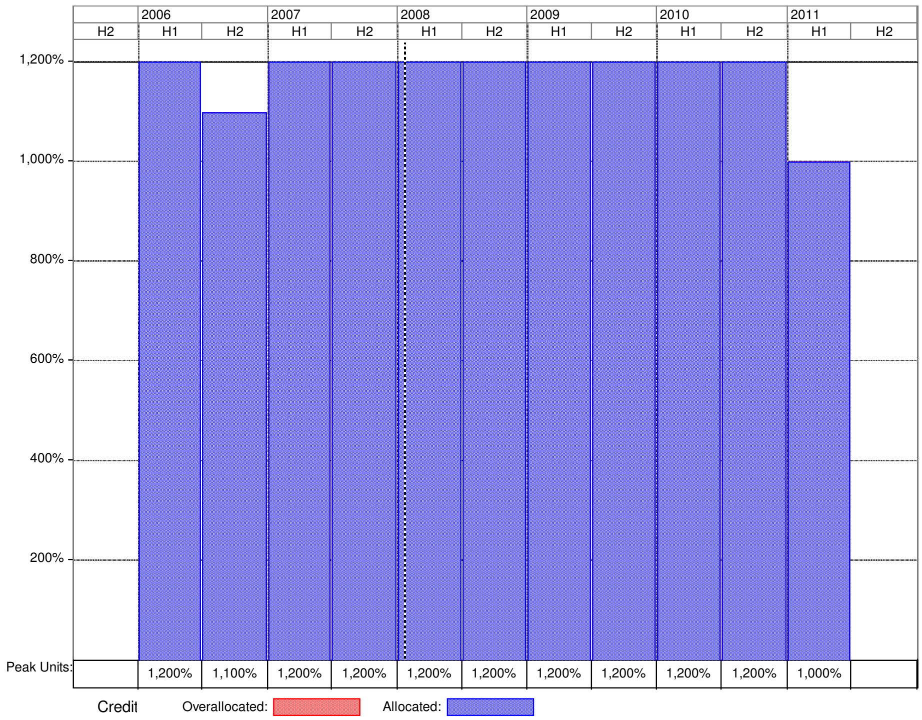


Figure 11, Credits Limited to 12 per Semester

Conclusions

It was demonstrated how to apply the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) to model the courses in a degree plan and identify the sequence that can produce a longer delay in the completion of the entire academic program. The use of project management tools permit the quick balancing of the available resources for a student thus allowing him to take the proper classes without adding unnecessary delays.

As future work we need to tune the model by collecting more statistics and enable the PERT features. This will give a probabilistic view that will highlight bottlenecks in the course sequences. In addition the automation and individualization of the charts will put the tool in the hands of each student so they can take charge of their own degree.

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