# Teaching of critical path networks using software packages

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**Abstract.** The aim of this paper is to review a published paper, 'Using computer software packages to enhance the teaching of Engineering Management Science: Part 1 –Critical path networks'. Excel in Microsoft Office 2007 was discovered to be able to solve critical path network problems with some programming. The capabilities of the two previously evaluated packages, Microsoft Project 2007 and Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3 were cited and Excel usage is explained for each of the objective of the module, critical path networks. A pseudo quantity scoring system was developed to evaluate the capabilities of the software packages in meeting the 5 objectives of the module. It was found that POM-QM for Windows 3 scored the highest points. However, Excel in MS can be argued to provide the best learning outcomes as it endeavours students to understand the concepts of critical path networks clearly before they can program and solve the problems.

*Keywords*: Engineering management science, Microsoft Project 2007, Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3, Excel in Microsoft Office 2007 and critical path networks,

## 1 Introduction

In the previous paper, it was found that both can be used to draw the CPA network diagrams but none of them is perfect as they can only draw them in activity-on-node. Only *POM-QM for Windows* 3 can be used to evaluate the earliest start, earliest finish, latest start and latest finish times, and calculate the total float for all activities and present them in a table; this still cannot satisfy all the requirements of objectives 3 and 4 of the modules as listed in Table 1 because the package cannot evaluate the free float and independent float [1]. For costing and crashing, *POM-QM for Windows* 3 is more suitable for the course as the package can solve the costing and crashing at activity level. In drawing Gantt chart and showing the critical path in the chart, *POM-QM for Windows* 3 is more suitable as it is simpler to use. It appears that *POM-QM for Windows* 3 is a better software for this module [1].

**Table 1: Objectives of the module, critical path networks**

| Objectives | Details |
|---|---|
| 1 | recognize situations where the application of critical path analysis (CPA) is appropriate; |
| 2 | break down a project into a number of suitable activities and construct a CPA network showing how these activities are combined in a logical sequence representing the project from start to finish; |
| 3 | analyze activities in critical path network in terms of activity start and finish times; |

In this paper, *Excel in MS Office 2007* will be tried in 5 objectives of the module, critical path networks. Each time, when *Excel* is tested for suitability of a particular objective of the module, the capabilities of the two previously used packages on the same objective will also be cited and discussed. Finally, a pseudo-quantitative score system will again be employed to evaluate the three packages to determine which one is the best for the module.

## 1.1 Excel in Objective 1

Neither *Excel*, nor the other two packages can be used to recognize situations where the application of critical path analysis (CPA) is appropriate. Students have to decide the above case by themselves without the help of any package.

## 1.2 Excel in Objective 2

Figure 1 shows the *POM-QM for Windows* 3 inputs for a project (used in previous paper) with activities, their duration and precedence, for constructing a critical path network. *Excel* cannot construct a CPA network showing how these activities are combined in a logical sequence representing the project from start to finish. This has to be done manually from information provided in Figure 1 and is depicted in Figure 2. On the other hand, *POM-QM for Windows 3* can generate a network diagram from inputs as shown in Figure 1; the critical path of the network will also be generated at the same time. With suitable inputs as, *MS Project* will generate a network diagram.

| | Activity time | Prec 1 | Prec 2 | Prec 3 | Prec 4 | Prec 5 | Prec 6 | Prec 7 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Budgeting | |
| 1-2 | 16 | | | | | | | |
| 1-3 | 20 | | | | | | | |
| 1-11 | 30 | | | | | | | |
| 2-8 | 15 | 1-2 | | | | | | |
| 3-7 | 15 | 1-3 | | | | | | |
| 3-8 | 10 | 1-3 | | | | | | |
| 7-8 | 3 | 3-7 | | | | | | |
| 7-11 | 16 | 3-7 | | | | | | |
| 8-11 | 12 | 7-8 | 3-8 | 2-8 | | | | |

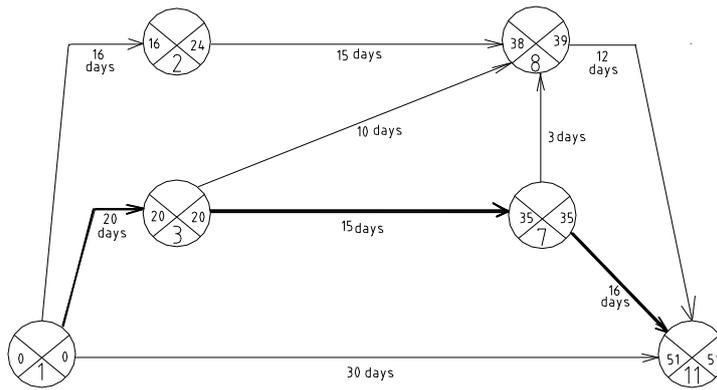**Figure 1: A project with activities, their duration and precedence**

**Figure 2: The network, its activities and durations with critical path drawn**

## 1.3 Excel in Objective 3

*Excel* can analyse activities in critical path network in terms of activity start and finish times by inputting the information into the spreadsheet as depicted in Figure 3. Start time for 'node 2' is calculated by referring to Figure 2 and adding duration of 'activity 1-2' to start time of 'node 1', i.e. 16 + 0 = 16 or inputting '=E3+C3' into cell E4 as depicted in Figure 4. Similarly, start time for 'node 3' is calculated by adding duration of 'activity 1-3' to start time of 'node 1', i.e. 20 + 0 = 20 or inputting '=E3+C4' into cell E5. However, start time for 'node 7' is calculated by adding duration of 'activity 3-7' to start time of 'node 3', i.e. 15 + 20 = 35 or inputting '=E5+C7' into cell E6. The start time of 'node 8' is more complicated to evaluate because three activities, '2-8', '3-7' and '7-8' terminate in 'node 8'. It has to be achieved by entering '=**MAX(E4+C6,E5+C8,E6+C9)**' into cell E7. This is the equivalent of evaluating it manually using forward pass method. Similarly, start time of 'node 11' is evaluated by inputting '=**MAX(E3+C5,E6+C10,E7+C11)**' into cell E8 [2]. All start and finish times for all nodes are shown in Figure 4; finish times will be worked similarly. Critical path is achieved by joining critical nodes, in which the difference between the start time and finish time of a node is zero. Critical nodes can be found by entering '=**IF(F3-E3=0,0,1)**' in cell G2 and copy it through cells G3 through G8. Critical nodes are illustrated and highlighted in Figure 4 [2]. The critical path is therefore 1-3-7-11. i.e. lines joining the critical nodes are the critical path but this has to be drawn manually as depicted in Figure 2.

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Activities | SD | D | Nodes | Start | Finish | CP=0 | ES | LS | EF | LF | TF | FF | IF |
| 2 | | | | | | | | | | | | | | |
| 3 | 1-2 | 0 | 16 | 1 | 0 | 0 | 0 | | | | | | | |
| 4 | 1-3 | 0 | 20 | 2 | | | | | | | | | | |
| 5 | 1-11 | 0 | 30 | 3 | | | | | | | | | | |
| 6 | 2-8 | 16 | 15 | 7 | | | | | | | | | | |
| 7 | 3-7 | 20 | 15 | 8 | | | | | | | | | | |
| 8 | 3-8 | 20 | 10 | 11 | | | | | | | | | | |
| 9 | 7-8 | 35 | 3 | | | | | | | | | | | |
| 10 | 7-11 | 35 | 16 | | | | | | | | | | | |
| 11 | 8-11 | 38 | 12 | | | | | | | | | | | |

**Figure 3: Inputs to Excel for evaluating node start and finish times**

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | Activities | SD | D | Nodes | Start | Finish | CP=0 |
| 2 | | | | | | | |
| 3 | 1-2 | 0 | 16 | 1 | 0 | 0 | 0 |
| 4 | 1-3 | 0 | 20 | 2 | 16 | 24 | 1 |
| 5 | 1-11 | 0 | 30 | 3 | 20 | 20 | 0 |
| 6 | 2-8 | 16 | 15 | 7 | 35 | 35 | 0 |
| 7 | 3-7 | 20 | 15 | 8 | 38 | 39 | 1 |
| 8 | 3-8 | 20 | 10 | 11 | 51 | 51 | 0 |
| 9 | 7-8 | 35 | 3 | | | | |
| 10 | 7-11 | 35 | 16 | | | | |
| 11 | 8-11 | 38 | 12 | | | | |

**Figure 4: Nodes start and finish times and critical nodes (highlighted)**

## 2 Discussions

In order to decide which software package is better for the module, a pseudo quantity evaluation method is employed, in which scores are allocated to each package when they satisfy a particular objective of the topic. Score of 0 to 10 will be awarded to each package for satisfying a particular objective, 10 being the highest and the package with highest total scores is considered to be more suitable software for the module.

For constructing network diagram (objective 2), *Excel* should score zero. The other two packages should score 7 because they are not very good at this. However, they can meet the desired outcome as learners can draw the CPA network diagram.

*Excel* can be used to evaluate the earliest start, earliest finish, latest start and latest finish times (objective 3) for all activities and present them in a table as depicted in Figure 5. The programming techniques required is not too difficult for engineering students but students must have a very good grasp of the concept of objectives 3 before they can program the software. This is good in the sense that students have to learn the underlying principles and do not rely on software packages to obtain the results. *POM-QM for Windows* 3 can be used to evaluate the earliest start, earliest finish, latest start and latest finish times, and calculate the total float for all activities and present them in a table. The package, however, was not able to evaluate the free and the independent floats. On the other hand, *MS Project 2007* cannot perform these functions. Only *Excel* and *POM-QM for Windows* 3 can meet the requirements of objectives 3 of the topic; this matches the desired outcomes as students can evaluate the earliest start, earliest finish, latest start and latest finish times, and calculate float availability and present them in a table; these are in line with the desired outcomes as learners learn objective 3.
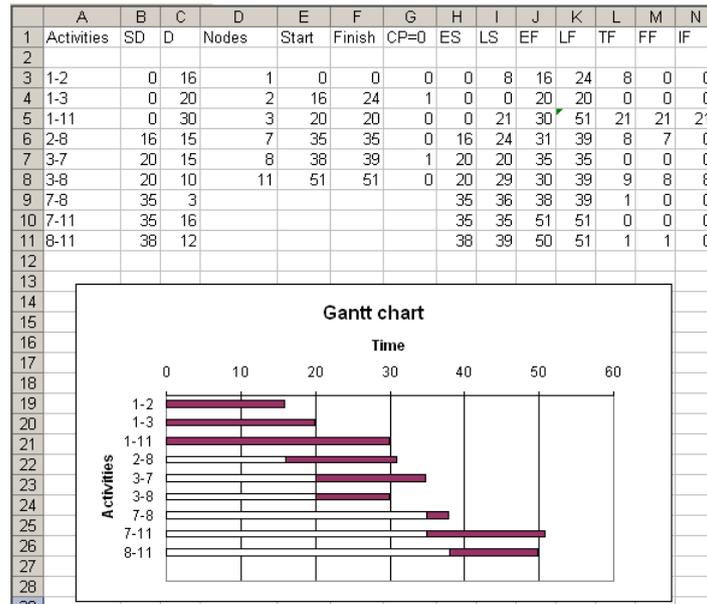
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Activities | SD | D | Nodes | Start | Finish | CP=0 | ES | LS | EF | LF | TF | FF | IF |
| 2 | | | | | | | | | | | | | | |
| 3 | 1-2 | 0 | 16 | 1 | 0 | 0 | 0 | 0 | 8 | 16 | 24 | 8 | 0 | 0 |
| 4 | 1-3 | 0 | 20 | 2 | 16 | 24 | 1 | 0 | 20 | 20 | 20 | 0 | 0 | 0 |
| 5 | 1-11 | 0 | 30 | 3 | 20 | 20 | 0 | 0 | 21 | 30 | 51 | 21 | 21 | 21 |
| 6 | 2-8 | 16 | 15 | 7 | 35 | 35 | 0 | 16 | 24 | 31 | 39 | 8 | 7 | 0 |
| 7 | 3-7 | 20 | 15 | 8 | 38 | 39 | 1 | 20 | 20 | 35 | 35 | 0 | 0 | 0 |
| 8 | 3-8 | 20 | 10 | 11 | 51 | 51 | 0 | 20 | 29 | 30 | 39 | 9 | 8 | 8 |
| 9 | 7-8 | 35 | 3 | | | | | 35 | 36 | 38 | 39 | 1 | 0 | 0 |
| 10 | 7-11 | 35 | 16 | | | | | 35 | 35 | 51 | 51 | 0 | 0 | 0 |
| 11 | 8-11 | 38 | 12 | | | | | 38 | 39 | 50 | 51 | 1 | 1 | 0 |

**Gantt chart**

**Time**

Activities: 1-2, 1-3, 1-11, 2-8, 3-7, 3-8, 7-8, 7-11, 8-11

**Figure 5: Completed Gantt chart**

In constructing Gantt chart, *Excel* can perform the work well but some programming technique is required. It can score 5 only because it cannot show critical path in the chart. Both packages, *MS Project 2007 and POM-QM for Windows 3* can create Gantt chart but *POM-QM for Windows* 3 can do better because it shows the critical path in the Gantt chart without requiring further operation.

The addition of three software packages to the topics in the course will certainly improve the academic standing of the course because its contents are now at par with most of international textbooks. Students will also be able to apply what they have learnt from the course to their workplace with ease as they will not need to do complicated iterations or calculations. All are done by standard software packages.

With reference to Table 2, it can be found that *POM-QM for Windows 3* (25) is still the best package for the module; *Excel* (11) comes next but it needs programming. The final one is *MS Project 2007* (8) given that it is relatively expensive and cannot perform some operations required by the five objectives [1].

**Table 2: Scores to the three software packages used**

| Factors considered | Software Packages | | |
|---|---|---|---|
| | *POM-QM for Windows 3* | *MS Project 2007* | *Excel in MS Office 2007* |
| Objective 1 | 0 | 0 | 0 |
| Objective 2 | 7 | 7 | 0 |
| Objective 3 | 8 | 0 | 10 |
| Price | 10 | 1 | 1 |
| Total scores | 25 | 8 | 11 |

From the above facts and arguments, it can be found that at different part of a problem, different software packages have to be used; sometimes, it is because that a package cannot perform the function required, and at times, one is more efficient than others.   Sometimes, both cannot perform the required function, e.g. in evaluating the free and independent floats [1].

**3 Conclusions**

For *critical path networks,* more than one package will be required; different packages will be required on different parts of the problem and no one package can satisfy the needs for beginners. *Excel* is a very good package for learning because students cannot use it to meets the objectives of the module unless they have a very good grasp of the concepts of the objectives.

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