

Using Computer Software Packages to Enhance the Teaching in Engineering Management Science Part 4 – Quality control

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Abstract— This paper is the fourth paper in a series of sharing the experience of using different software packages in the delivery of *Engineering Management Science* coded as ENG4004, in the Bachelor of Engineering and Bachelor of Engineering Technology programs offered by the University of Southern Queensland. The paper describes how the authors use different software packages to solve the *Quality Control* problems of the course. Sometimes more than one package is required for the effective delivery of a topic of the course. The needs for the usage were also explained. The assessments of the course were also studied and reviewed. How the software packages met the objectives of the module were also discussed together with the desired learning outcomes of students. The preferred software was *Excel in MS Office 2007*. It can be argued that the students' learning experience and satisfaction will be greatly increased with the software packages while the cost to the university will be minimal.

Index Terms — Engineering management science, Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3, Excel in Microsoft Office 2007, quality control, control charts and cusum charts.

I. INTRODUCTION

THE application of computers in engineering education is now much more than simply teaching students to use programming languages, e.g. Visual Basic. It also teaches how to use certain software packages to solve the problems in their course. Computer and its related software had long been used in the routine design work in university courses and workplace [1]. In USQ, *Engineering Management Science* (EMS) is offered as the core course to seven engineering degree programs, ranging from building and construction management to mechatronic engineering. It is a one-semester course and is offered in semester two (2) every year and semester three (3) in alternate years. In addition, the course is also offered as face-to-face on-campus study as well as print based delivery, in which studybooks and other materials, e.g. CD-ROM are mailed to students worldwide. Additional support given to off-campus students includes communication by telephone, e-mails and Moodle (web-based computer technology) through the Internet [2]. For the on-campus study, the course is currently available only at Toowoomba campus (Other campuses are in Fraser Coast

and Springfield). Today, *Engineering Management Science* software packages have been mainly developed by software companies and individuals who have ample knowledge about the subject [3]. In USQ, the course is delivered to both on-campus and off-campus students and this adds to the challenge of delivering the course successfully. Just like in some of the previous papers of the same series [4]–[6], the software packages used in this case consist of the previously used *Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3* written by Howard J Weiss [7] and *Excel in Microsoft Office 2007* (MS Office 2007). The cost to the university will be the same as in the second paper of the same series.

II. COURSEWARE AND SOFTWARE PACKAGES

The present courseware of *Engineering Management Science* (EMS), ENG4004 consists of five topics: critical path networks, programming techniques, simulations, quality control and micro-economic functions. In the past, the course has been offered without using any software packages. Students learned the principles and theories of different models in EMS; they were taught to solve simple problems manually but enrichment to the course is now necessary. One enrichment necessary is the additional use of software packages, like POM-QM for Windows 3 for the first topic, Critical Path Networks [4]. If these were absent, people may think that the course is out of date as most engineering science management textbooks have included them. The next question is how to select a package that suits the remaining 2 topics in ENG4004 in USQ. Turban and Erikson [3] discussed the selection of engineering management science software for PCs in details. The first step of the selection process is defining the problem. The fourth module of the course, ENG 4004 is Quality Control and Keytack [8] mentioned that several textbooks had started to include a software package that deals with most of the decision science problems as early as 1994. This means that POM-QM for Windows 3 could be one of the suitable packages [7]. On account of the characteristics and functions of spreadsheet, it is believed that it can be used as a software package in Quality Control and the most commonly found spread sheet will be Excel in MS office 2007. After discussions and consultations with colleagues, the authors were not able to identify any other software package suitable for Quality Control.

There are five parts in the series of these articles: the first one is the use of software packages in delivering critical path networks; the second is the application of software packages in programming techniques: distribution method and simplex

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method; the third is the utilization of software packages in delivering simulation using Monte Carlo technique; the fourth is the utilization of software packages in delivering quality control; the last one is the use of software packages in delivering financial analysis: break even analysis and net present value. The topics covered in five parts constitute the modules in the course, *Engineering Management Science*.

This paper is the fourth in the series and covers the application of software packages in quality control. Unlike the previous paper of the same series, the software packages used in this case consist of the previously used *Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3* written by Howard J Weiss [7] and *Excel in Microsoft Office 2007 (MS Office 2007)*. This will cost the university even less than the previous case, the use of software packages in delivering critical path networks.

III. QUALITY CONTROL PACKAGES

The first application of a package to quality control is calculating the limits of the average chart (x-chart) and the range chart (w-chart) and then plot them out together with the variables considered. Both *Excel in MS Office 2007* and *POM-QM for Windows 3* are able to solve such problems. Consider a quality control problem (in ENG4004 studybook) as tabulated in Tables I and II.

Table I
Example of quality control problem

A seafood company sells fish, prawn, crabs, lobsters etc. depending on their availability throughout the year. Operations are manual because of the small batches processes at one time. The weights of the packed containers are critical as the product is high cost and the company's salesmen have to account for any large weight discrepancies especially it disadvantages the customer. Prawns are packed in 0.5, 1 and 2 kilogram containers during weighting. The weighing process involves the worker scooping a quantity of prawns into the container and then adding or removing a few prawns by hand to achieve the correct weight. Workers are paid on a contract basis according to the number of containers they fill; hence speed is an essential part of the weighing operation. Because of the backlash from dissatisfied customers it is necessary to ensure underweighting is kept to a minimum, hence the weighing range is specified as: $1 \pm \frac{0.06}{0.04}$ kg for the 1 kg containers.

A sampling program is used to test the accuracy of the process and ten samples were taken each day by selection of containers during the day. The results of weighing 10 samples of five 1 kg. containers are shown in Table II.

The problem was first solved with *Excel in MS Office 2007*. The spreadsheet model is shown in Fig. 1. To develop this model, perform the following steps:

1. Enter the sample number in the range of **A5:A14** and **A21:A30**.

Table II
Weight of containers in samples

Sample Number	Weight of containers in samples (kgs)					Average weight, x	Range, w
1	1.04	1.01	0.98	1.02	1.00	1.01	0.06
2	1.02	0.97	0.96	1.01	1.02	0.996	0.06
3	1.01	1.07	0.99	1.03	1.00	1.02	0.08
4	0.98	0.97	1.02	0.98	0.98	0.986	0.05
5	0.99	1.03	0.98	1.02	1.01	1.006	0.04
6	1.02	0.95	1.04	1.02	0.95	0.996	0.09
7	1.00	0.99	1.01	1.02	1.01	1.006	0.03
8	0.99	1.02	1.00	1.04	1.09	1.028	0.1
9	1.03	1.04	0.99	1.02	0.94	1.004	0.1
10	1.02	0.98	1.00	0.99	1.02	1.002	0.04
						1.0054	0.065

A	B	C	D	E	F	G	H	I	J	K	
Example - Construction of an x-chart & a w-chart											
Sample	Weight_1	Weight_2	Weight_3	Weight_4	Weight_5	Average weight, x	Range, w				
1	1.04	1.01	0.98	1.02	1.00	1.01	0.06				
2	1.02	0.97	0.96	1.01	1.02	0.996	0.06			UCL = 0.1195	
3	1.01	1.07	0.99	1.03	1.00	1.02	0.08			UAL = 0.1558	
4	0.98	0.97	1.02	0.98	0.98	0.986	0.05			Average weight	
5	0.99	1.03	0.98	1.02	1.01	1.006	0.05			UCL = 1.0305	
6	1.02	0.95	1.04	1.02	0.95	0.996	0.09			UCL = 0.9803	
7	1.00	0.99	1.01	1.02	1.01	1.006	0.03			UAL = 1.0443	
8	0.99	1.02	1.00	1.04	1.09	1.028	0.1			LAL = 0.9665	
9	1.03	1.04	0.99	1.02	0.94	1.004	0.1				
10	1.02	0.98	1.00	0.99	1.02	1.002	0.04				
Grand average, X =						1.0054					
Average, W =							0.065				
Sample	Average, w	UCL	UAL	Range, w	Grand average, X	UCL	LCL	UAL	LAL	Average weight, x	
0	0.065	0.1177	0.1534		1.0054	1.03048	0.98032	1.0443	0.966		
1	0.065	0.1177	0.1534	0.06	1.0054	1.03048	0.98032	1.0443	0.966	1.01	
2	0.065	0.1177	0.1534	0.06	1.0054	1.03048	0.98032	1.0443	0.966	0.996	
3	0.065	0.1177	0.1534	0.08	1.0054	1.03048	0.98032	1.0443	0.966	1.02	
4	0.065	0.1177	0.1534	0.05	1.0054	1.03048	0.98032	1.0443	0.966	0.985	
5	0.065	0.1177	0.1534	0.04	1.0054	1.03048	0.98032	1.0443	0.966	1.006	
6	0.065	0.1177	0.1534	0.09	1.0054	1.03048	0.98032	1.0443	0.966	0.996	
7	0.065	0.1177	0.1534	0.03	1.0054	1.03048	0.98032	1.0443	0.966	1.006	
8	0.065	0.1177	0.1534	0.1	1.0054	1.03048	0.98032	1.0443	0.966	1.028	
9	0.065	0.1177	0.1534	0.1	1.0054	1.03048	0.98032	1.0443	0.966	1.004	
10	0.065	0.1177	0.1534	0.04	1.0054	1.03048	0.98032	1.0443	0.966	1.002	

Fig. 1. Spreadsheet model for quality control problem

2. Enter the sample number in the range of **A5:A14** and **A21:A30**.
3. Enter the 5 weights for the first sample in the range of **B5:F5**. Repeat for samples 2 through 10 in the range of **B6:B14**.
4. Evaluate average weight, x for sample 1. In cell G5 compute the average value, x by entering the formula = **SUM(B5:F5)/5**. By copying G5 into **G6:G14**, evaluate the average weights for samples 2 through 10.
5. Evaluate grand average weight, X. In cell G15 compute the grand average weight, X by entering the formula = **SUM(B5:B14)/10**.
6. Evaluate range, w for sample 1. Enter =(MAX(B5:F5) - (MIN(B5:F5))) into cell H5. Copy H5 into **H6:H14** for w of samples 2 through 10.
7. Evaluate grand range, W. In cell H16 compute the grand range, W by entering the formula = **SUM(H5:H14)/10**.
8. Evaluate the UCL for the range. In cell K5 compute the UCL by entering the formula = **1.81*H16#**. #1.81 is a constant for UCL for range and can be obtained from a table.
9. Evaluate the UAL for the range. In cell K6 compute the UAL by entering the formula = **2.36*H16#**. #2.36 is a constant for UAL for range and can be obtained from a table in the studybook.
10. Evaluate the UCL for the average. In cell K9 compute the UCL by entering the formula = **\$G\$15+0.38*H16#**.

*1.0054 is the grand average, \bar{X} and 0.38 is a constant for UCL and LCL for average and can be obtained from a table in the studybook.

11. **Evaluate the LCL for the average.** In cell K10 compute the LCL by entering the formula = $GG\$15 - 0.38 * H16$.*
12. **Evaluate the UAL for the average.** In cell K11 compute the UACL by entering the formula = $GG\$15 + 0.59 * H16$.*
*1.0054 is the grand average, \bar{X} and 0.59 is a constant for UAL and LAL for average and can be obtained from a table.
13. **Evaluate the LAL for the average.** In cell K12 compute the UACL by entering the formula = $GG\$15 - 0.59 * H16$.*

The w-chart shown in Fig. 2 was constructed by the following steps:

14. **Select**/highlight the range A21:E30.
15. **Click** the “Chart Wizard” icon on the toolbar at the top of the spreadsheet. The first screen for the Chart Wizard (step 1) allows you to select the “Chart Type”.
16. **Select** the “Line” chart; then click the “Next” button and the step 2 window appears
17. **Click** on the “Series” tab. In the “Series” window, specify the cell values for each series of data one wants to plot on the chart.
18. **Save** the chart.

The x-chart shown in Fig. 3 was also constructed by similar steps. Similarly, *Excel in MS Office 2007* can also be used to solve and plot control charts for attributes: p-chart and c-chart.

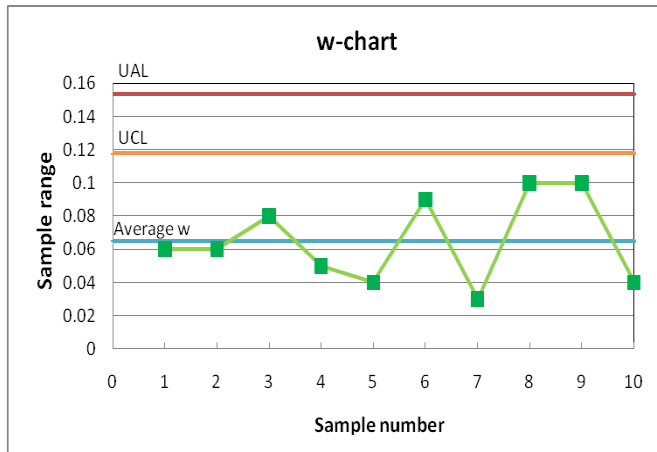


Fig. 2. Range chart

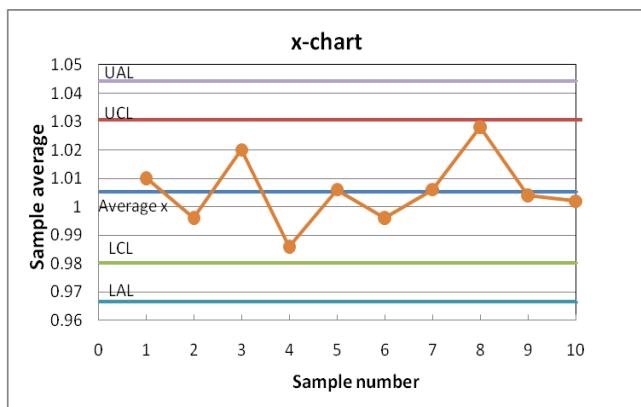


Fig. 3. Average chart

To solve the problem using *POM-QM for Windows 3*, one needs to input the weight of the containers in the samples into the template provided (Fig. 4). Number of rows can be increased when required to accommodate more samples. After this, click the ‘Solve’ button near the top right hand corner of the screen to run the program. Quality control results will be generated by the computer. The results generated include average weight and average range together with the upper and lower limits for both charts as well as their centre lines as depicted in Fig. 5 and 6.

Sample Number	Item 1	Item 2	Item 3	Item 4	Item 5
1	1.04	1.01	.98	1.02	1
2	1.02	.97	.96	1.01	1.02
3	1.01	1.07	.99	1.03	1
4	.98	.97	1.02	.98	.98
5	.99	1.03	.98	1.02	1.01
6	1.02	.95	1.04	1.02	.95
7	1	.99	1.01	1.02	1.01
8	.99	1.02	1	1.04	1.09
9	1.03	1.04	.99	1.02	.94
10	1.02	.98	1	.99	1.02

Fig. 4. Input to POM-QM for Windows 3 for quality control problem

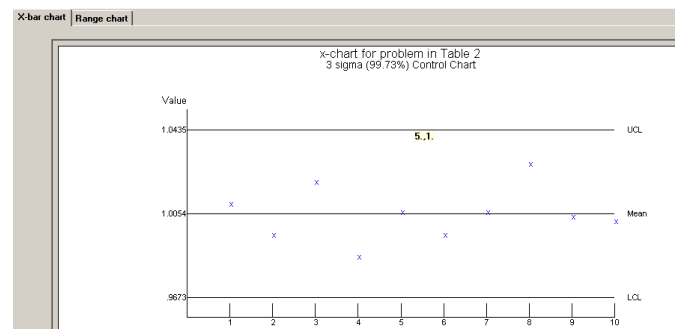


Fig. 5. x-chart for problem in Table II

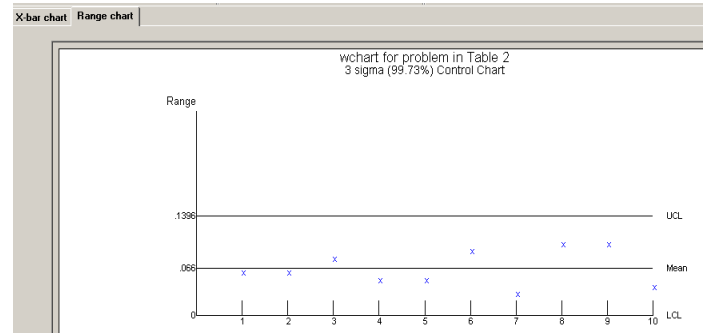


Fig. 6. w-chart for problem in Table II

Both packages require inputting certain amount of information; it appears that *POM-QM for Windows 3* is a more professional software than *Excel in MS Office 2007* for solving problems in quality control. The former requires no calculation at all. On the other hand, *Excel* requires some simple programming of the spreadsheet. *POM-QM for Windows 3* plots the charts automatically. On the other hand, some techniques are required to plot the charts from *Excel in MS Office 2007*. In short, *POM-QM for Windows 3* seems to be the preferred package in this case because it has less chance of making mistakes by not requiring calculation

and plotting the charts. The only problem with this package was that the variables plotted on the charts were not joined as in the case of its counterpart.

The second application of a package to quality control is developing a cumulative sum chart. To illustrate this, an example was taken for discussion and tabled in Tables III and IV.

Table III
Example of cusum chart problem

An automatic devise dispenses pellets into packages. It is desirable that the number of pellets in each package should be within the specified range 2000 ± 100 . The performance of the device is monitored over a period of two, eight-hour shifts. A sample of six packages is taken every hour and the number of pellets in each pellet is counted. The results are summarized in Table IV. Accurately sketch a cusum chart and comment briefly on nav trends that are evident.

Table IV
Data for Table III cusum chart

Sample Number.	Average no. of pellets
1	1978
2	1957
3	1956
4	1962
5	1962
6	1958
7	1983
8	1964
9	1983
10	1996
11	2002
12	1987
13	2004
14	1993
15	2002
16	1993
Grand average	1980

	A	B	C	D
1	Sample No.	\bar{x}	$\bar{x} - k$	cusum
2				
3	1	1978	-2	-2
4	2	1957	-23	-25
5	3	1956	-24	-49
6	4	1962	-18	-67
7	5	1962	-18	-85
8	6	1958	-22	-107
9	7	1983	3	-104
10	8	1964	-16	-120
11	9	1983	3	-117
12	10	1996	16	-101
13	11	2002	22	-79
14	12	1987	7	-72
15	13	2004	24	-48
16	14	1993	13	-35
17	15	2002	22	-13
18	16	1993	13	0

Fig. 7. Spreadsheet model for (cusum chart problem)

Use the grand average as the constant, k to be deducted. *Excel in MS Office 2007* was employed to do this. The spreadsheet model is shown in Fig. 7. To develop this model, perform the following steps:

1. Enter the values of \bar{x} in the range of **B3:B18**.
2. Enter “=B3-1980” to C3. Copy C3 into **C4:C18**.
3. Enter “=C2+C3” into D3. Copy D3 into **D4:D18**.
4. Select/highlight the range **D3:D18**.
5. Click the “Chart Wizard” icon on the toolbar at the top of the spreadsheet. The first screen for the Chart Wizard (step 1) allows you to select the “Chart Type”.
6. Select the “Line” chart; then click the “Next” button and the step 2 window appears.
7. Click on the “Series” tab. In the “Series” window, specify the cell values for each series of data one wants to plot on the chart.
8. Save the chart.

Fig. 8 illustrates the cusum values against sample number. The two gradients have to be added manually. The mean value, \bar{a} over any portion of the cusum chart is given by

$$[9]: \bar{a} = k + \frac{\text{change_in_cumulative_sum}}{\text{change_in_n}}$$

Mean value for the first eight hours
 $=1980 + [-120 - (-2)]/7$
 $=1980 + [-118]/7$

$=1966.85 \approx 1960$.

Mean value for the second shift
 $=1980 + [0 - (-117)]/7$
 $=1980 + [+117]/7$
 $=1996.71 \approx 2000$.

For the first eight hours, the average is low at 1960. Re-set the machine to dispense 2000 pellets. There is then a significant change at the change of shift. For the second shift, the average is 2000. On the other hand, *POM-QM for Windows 3* cannot evaluate the cusum and plot its chart.

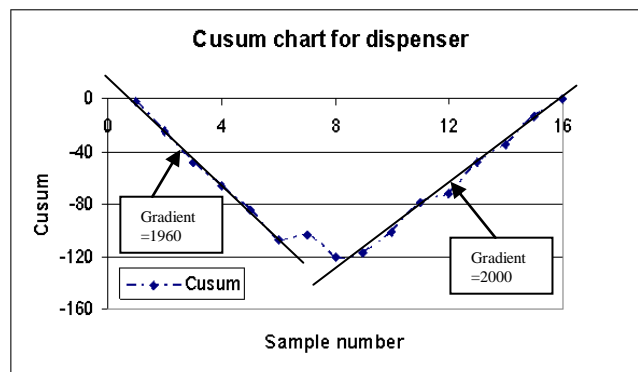


Fig. 8. Cusum chart for dispenser Assessment

At the moment, there were three assessments for the course, two assignments and one examination. Starting from S2, 2009, the first assignment will deal with critical path network analysis with a weight of 15%; the other one will be for distribution method or simplex method (programming techniques), simulation and quality control respectively with a weight of 25%. Suggested solutions with marking schemes were sent to students via Moodle on the due date of each assignment and no extension of assignments was permitted. External students handed in their assignments by mail via the USQ Distance and e-Learning Centre and were returned to them via the same pathway. Students are expected to spend about four hours on each assignment. The last assessment is a 2-hour open book examination which consists of five questions and contributes to 60% of the total marks. The first question is a compulsory question based on critical path networks and contributes 150 of the total marks of the course. The other four questions covered the remainder of the topics; students were required to attempt any three of them; each contributes 150 of the total marks [9].

In this paper, only part of the second assignment – quality control and micro-economic functions will be discussed. The quality control question of assignment 2, S2, 2009 describes that a ready-mix concrete supplier delivers by truck to a dam site. Each truck is specified as containing 4800 ± 50 kg. The supplier is concerned that his automatic concrete dispenser may not be capable of working to such a tight tolerance and therefore deliberately dispensing more than 4800 kg per truck. Table V illustrates the average truck load and range of each sample of five over fifteen days. Students are required to plot the range chart and the average chart (i) manual method and (ii) using *POM-QM for Windows 3* students are required to submit their work for part (ii) in a CD-ROM]. Solving the problem manually is not difficult but tedious. On the other hand solving the problem using *POM-QM for Windows 3* is just inputting the average and range values into the template of the package.

Table V.

Average truck load and range of each sample of five over fifteen days

Sample Number	Sample Average, x, kg	Range, w, kg
1	4853	52
2	4848	18
3	4849	26
4	4873	42
5	4866	38
6	4862	49
7	4865	33
8	4858	19
9	4872	44
10	4849	50
11	4861	42
12	4857	43
13	4871	36
14	4852	25
15	4864	53

IV. DISCUSSION

The objectives of the module, quality control, consist of [9]:

- (i) describe the application of control charts for controlling process variables and attributes;
- (ii) demonstrate the use of control charts for controlling process variables and attributes given short term data from the process;
- (iii) interpret control charts in terms of process performance and state what action is necessary as a result;
- (iv) show how the control chart technique can be modified to take into account three levels of precision found in the process control;
- (v) appraise the role and importance of control charts in the overall concept of Quality Control within an organization;
- (vi) construct and interpret cumulative sum (cusum) charts.

How well do these software packages satisfy the objectives of the module? Both packages can solve problems of control charts for controlling process variables and attributes and they are shown in Fig. 1 to 3 (*Excel in MS Office 2007*) and 4 to 6 (*POM-QM for Windows 3*) respectively. Both packages can satisfy the objectives 2, 3 and 4 of the module; this matches the desired outcomes as students can demonstrate the use of control charts for controlling process variables and attributes given short term data from the process, and interpret control charts in terms of process performance and state what action is necessary as a result, and show how the control chart technique can be modified to take into account three levels of precision found in the process control.

As far as quality control in ENG 4004, *Engineering Management Science* is concerned; it appears that *POM-QM for Windows 3* appears to be a better tool to solve the problems. Students can solve the problems by just inputting the data into the template of *POM-QM for Windows 3*; the lower and upper limits of the charts as well as their centre lines will be generated once the program is run. The maximum sample number for this package is 90 and its sample size is 25. This will be enough for most applications. There is only a minor problem about the chart produced. The variables plotted on the charts are not joined

together and it seems that it is more difficult to identify the pattern of the variables as depicted in Fig. 5 and 6 (for *POM-QM for Windows 3*). On the other hand, it was easy to recognize the pattern of the variables plotted by *Excel in MS Office 2007* as depicted in Fig. 2. On top of it, the charts produced by *Excel in MS Office 2007* are more colourful than their counterparts. On the other hand, if *Excel in MS Office 2007* were used to solve the quality control problem; some programming techniques will be required. The plotting of charts is also semi-automatic. However, the x-charts of both packages as shown in Fig. 3 and 5 respectively did not take into account the upper and lower specification limits as depicted by Deshpande [10].

Only *Excel in MS Office 2007* can evaluate the cusum and plot its chart. This is shown in Fig. 8. Only this package can satisfy the objective 6 of the module; this matches the desired outcomes as students can construct and interpret cumulative sum (cusum) charts. However, the plotting of the chart was semi-automatic and the gradients had to be separately calculated and input to Fig. 8.

In order to decide which software package is better for the module, a pseudo quantity evaluation method is employed, in which '+' is allocated for better, '0' is allocated for neutral and '-' is allocated for worst to each package depending on the performance of the package on each objective of the topic. Table VI shows the number of '+', '0' and '-' allocated to each software package. As the total '+' of *POM-QM for Windows 3* ('+' = 0, '0' = 4, '-' = 3) is lower than that of *Excel in MS Office 2007* ('+' = 1, '0' = 4, '-' = 2), the latter is therefore considered to be slightly more suitable package for the module.

The new form of assignments, in which students are required to solve problems using software packages as well as manually, will be implemented in semester 2, 2012. It can also be argued that some authors are also working on something similar to the authors of this paper. All of them use software packages to teach certain engineering courses other than engineering management science but all are enhancing their learning and teaching by using relevant software packages [11]-[18].

V. CONCLUSIONS

In the first the paper in this series, the authors conclude that different software will be required to solve different part of critical path network problems, i.e. cocktail software - *POM-QM for Windows 3* and *MS Project 2007* [4]. However, in the second paper in the same series, it was discovered that *Excel* would do the required jobs more properly [5]. In the third paper, again *Excel* was found to be the only package that can perform the required two variables simulation problems. In this paper, it was found that *Excel in MS Office 2007* is powerful than its counterpart, *POM-QM for Windows 3* because only the former can evaluate the cusum and plot its chart. Table VI shows that both packages are unable to solve the problems of Objective 1. Both can solve the problems of distribution of Objective 2 but *POM-QM for Windows 3* can do the job better. As far as Objectives 3 and 4 are concerned, both can do the same equally. Both cannot perform on Objective 5 and scored zero. Only *Excel* can perform Objective 6. Their prices are equally friendly as *Excel* comes with *MS Office 2007* and *POM-QM for Windows 3* comes with the text book.

Overall, Excel is better and scored ‘+’ = 1, ‘0’ = 4 and ‘-’ = 2 as depicted in Table VI. This was also indicated by Iglesias and Paniagua [11].

Both packages are likely to have the same functionality. However, students may not be familiar with programming them as only Excel programming were taught in one of their academic courses. But, it can be argued that engineering students can learn them with ease.

Table VI
Scores to the two software packages used

	Software Packages	
Factors considered	<i>POM-QM for Windows 3</i>	<i>Excel in MS Office 2007</i>
Objective 1	-	-
Objective 2	0	0
Objective 3	0	0
Objective 4	0	0
Objective 5	-	-
Objective 6	-	+
Price	0	0
Total allocations	‘+’ = 0, ‘0’ = 4, ‘-’ = 3	‘+’ = 1, ‘0’ = 4, ‘-’ = 2

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