

**Using computer software packages to enhance the teaching in Engineering  
Management Science: Part 2 –Programming techniques**

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## ***Abstract***

This paper is the second 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 programming techniques 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 comparative measure of the two packages used, *Excel in MS Office 2007* and *Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3* ended with the former as winner. 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.

***Keywords:*** engineering management science, Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3, Excel in Microsoft Office, linear programming, simplex method and distribution method.

## ***Introduction***

In the routine design work in university courses and workplace a lot of software packages had long been used to solve the problems in the courses [1]. The teaching of computers in engineering education is more than teaching programming languages,

e.g. C++. Software packages for certain applications have also been taught. At USQ, *Engineering Management Science* (EMS) is offered as a core course to seven engineering degree programs, ranging from building and construction management to mechatronic engineering. It is offered in semester two (2) every year and semester three (3) every second year. The course has a face-to-face on-campus mode as well as print based delivery mode, in which studybooks and other materials, e.g. CD-ROM are mailed to students worldwide. Off-campus students are supported communication by telephone, e-mails and Moodle (web-based computer technology) via the Internet [2]. For on-campus mode, 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.

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 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 second one in the series and covers the application of software packages in programming techniques: distribution method and simplex method.

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 [4] 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.

### ***Courseware and software package***

The present courseware of *Engineering Management Science (EMS)*, ENG4004 consists of five topics which are listed in Table 1. In the past, the course has been offered without using any software packages. Students study principles and theories of a range of topics in EMS; they learn to solve simple problems manually but enrichment to the course is now necessary. Such an enrichment is the use of software packages, like *Microsoft Quantitative Methods – Production and Operations Management (POM-QM) for Windows 3* for the first topic, *Critical Path Networks* [5]. If these were absent, people might think that the course is out of date as most engineering science management textbooks included them. The next phase is to select a package that suits the remaining 4 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 second module of the course, ENG 4004 is *Programming Techniques* and Keytack [6] stated that several textbooks 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 [4].

### ***Programming techniques packages***

The first application of a package to programming techniques may be used in distribution method. Both *Excel in MS Office 2007* and *POM-QM for Windows 3* are able to solve such problems. Consider a distribution problem (in ENG4004 studybook) as tabulated in Table 2 [7]. There are three departments A, B and C with an excess of pallets and that there are four departments, W, X, Y and Z which require pallets. The matrix is a from/to type with the departments requiring pallets shown horizontally, W, X, Y and Z and their individual requirements shown at the bottom of each column, i.e. 7, 10, 6 and 9 and the total requirement (32) in the bottom right hand corner square. Departments with excess pallets, A, B and C are shown vertically with their availabilities in each row shown on the right hand side, i.e. 8, 3, 11 and the total available pallets (32) in the bottom right hand corner. This problem assumes equal requirements and availabilities in this instance. The time taken to transport between departments is shown in the small box in each square of the matrix e.g. the round trip from department A to W is 10 minutes.

The problem is to distribute pallets from A, B and C to W, X, Y and Z in such a way that time spent is minimum. Northwest corner method is adopted in an arbitrary manner, ignoring the time. Department W requires 7 and department A has 8, therefore giving W its 7 pallets and putting the remaining 1 pallet in department X which requires 10. Now A has no pallets left, so the remaining 9 which X requires can come from B. B has a total of 13 and the remaining 4 which it has left, can go to Y which requires 6. C can supply Y with the other 2 leaving 9 which can be allocated to Z. The distribution is shown in the upper (highlighted) matrix of a spread sheet model depicted in Figure 1. The total time required:

$$A \rightarrow W = 7 \times 10 = 70 \text{ minutes}$$

$$A \rightarrow X = 1 \times 22 = 22 \text{ minutes}$$

$$B \rightarrow X = 9 \times 20 = 180 \text{ minutes}$$

$$B \rightarrow Y = 4 \times 12 = 48 \text{ minutes}$$

$$C \rightarrow Y = 2 \times 10 = 20 \text{ minutes}$$

$$C \rightarrow Z = 9 \times 15 = \underline{135 \text{ minutes}}$$

$$\text{Total} = \underline{475 \text{ minutes}}$$

The total time to effect this distribution is 475 minutes. This is also shown in the squared (highlighted) box in Figure 1. A method of improving on this time is to evaluate the remaining squares successively and when improvements are indicated pallets are moved to affect the desired change. To do this, using *Excel* with its Solver, another matrix has to be developed, which consists of the distribution time from dispatching departments to receiving departments as shown in the lower (not highlighted) matrix in Figure 1.

The information below explains the required inputs to the spreadsheet:

1. Enter the trial allocation of pallets from each distributing department (A, B and C) to each receiving department (W, X, Y and Z) in the range **C6:F8**.
2. Enter the time required to move items from each distributing department (A, B and C) to each receiving department (W, X, Y and Z) in the range **C18:F20**

3. To ensure that a distributing department, e.g. **A** does not distribute more than its available supply. In cell **G6**, compute the amount distributed to receiving departments by department **A** with the formula **=SUM(C6:F6)**. Enter '**<=**' into cell **H6** and the number of pallets available into cell **I6**. Repeat the procedures for departments **B** and **C**
4. To ensure that each receiving department receives the needed pallets, the pallets received by each department e.g. **W** are computed by entering the formula **=SUM(C6:C8)** in cell **C9**. Enter '**>=**' into cell **C10** and the number of pallets required into cell **C11**. Repeat the procedures for departments **X**, **Y** and **Z**.
5. Compute the total distance moved from each distributing department to each receiving department by entering the target cell, **C12** with the formula **=SUMPRODUCT(C6:F8,C18:F20)**. This formula simply sums all pallets distribution distance multiplied by units distributed.
6. To get access to the **Solver**, click 'Tools' menu on the toolbar. Click **Solver** and **Solver** screen as shown in Figure 2 appears.
7. Enter **C12** as the target (total distance moved) cell (Excel adds the \$\$) and check **Min** as the objective to minimize distance moved.
8. Enter **C6:F8** into the "changing cell" box of Figure 2 (Excel adds the \$\$).

9. Enter the supply constraints G6:G9 <= I6:I9 (Excel adds the \$\$) in the constraint box of Figure 2. These constraints ensure that no department distributes pallets exceeding its capacity. Step 9 supplies the constraints to Solver to ensure the program works, while step 6 only shows them in the matrix so that readers can read the matrix with ease.
  
10. Enter the demand constraints C9:F9 >= C112:F11 in the constraint box of Figure 2. These constraints ensure that each receiving department receives enough pallets.
  
11. Click 'Options' in Figure 2 and Figure 3 will pop up. Activate 'Assume linear model' as well as 'Assume non-negative'.
  
12. Move the cursor to the target cell, C12. Click 'Solve' of Figure 2 and the solution will be obtained and shown in Figure 4. Read the target cell, C12 and it can be found that the minimum distance is 330.

To solve the problem using *POM-QM for Windows 3*, one needs to re-structure the transportation table into simplex method equations. If  $V_{AW}$  is the number of pallets transferred from department A to department W and  $V_{BY}$  is the number of pallets transferred from department B to department Y, then

the objective function is to minimize  $10V_{AW} + 22V_{AX} + 10V_{AY} + 20V_{AZ} + 15V_{BW} + 12V_{BX} + 12V_{BY} + 8V_{BZ} + 20V_{CW} + 20V_{CX} + 10V_{CY} + 15V_{CZ}$

subject to constraints of

$$10V_{AW} + 22V_{AX} + 10V_{AY} + 20V_{AZ} \leq 8$$

$$15V_{BW} + 12V_{BX} + 12V_{BY} + 8V_{BZ} \leq 13$$

$$20V_{CW} + 20V_{CX} + 10V_{CY} + 15V_{CZ} \leq 11$$

$$10V_{AW} + 15V_{BW} + 10V_{CW} \geq 7$$

$$22V_{AX} + 12V_{BX} + 20V_{CX} \geq 10$$

$$10V_{AY} + 12V_{BY} + 10V_{CY} \geq 6$$

$$20V_{AZ} + 8V_{BZ} + 15V_{CZ} \geq 9$$

Input the objective function and the constraints into the boxes provided by the package as depicted in Figure 5. Click the ‘Solve’ and the results shown in Figure 6 will appear. From Figure 6 (last or solution row), it can be found that  $V_{AW} = 7$ ,  $V_{AY} = 1$ ,  $V_{BY} = 4$ ,  $V_{BZ} = 9$ ,  $V_{CX} = 10$ ,  $V_{CY} = 1$  and the total time required is 330 minutes. The dual of the problem is also shown in the results.

Both packages require inputting considerable amount of information; it appears that *POM-QM for Windows 3* is more troublesome as it requires re-structuring the transportation table into simplex method equations which may be prone to errors. However, it requires no programming at all. On the other hand, *Excel* requires some simple spreadsheet programming. The programming is relatively easy and it provides a mind challenge to engineering students. In short, *Excel* is preferred in this case because it gives less chance of making mistakes in re-structuring the transportation table, and in inputting less information as compared to its counterpart.

The other sub-topic in programming techniques is simplex methods. To start with, the authors will solve one of the existing distribution problems in the study book of the course using the *Excel Solver* of the spreadsheet. The problem mentions that a factory

manufactures washers and dryers. Parts are made in the Stamping and Motor-Transmission Department whilst assembly is done in the Washer Assembly Department and Dryer Assembly Department. Monthly capacities of these departments are:

Stamping Department	-	10,000 washers or 10,000 dryers
Motor-Transmission Department	-	16,000 washers or 7,000 dryers
Washer Assembly Department	-	9,000 washers
Dryer Assembly Department	-	5,000 dryers

A spreadsheet model (matrix) was first developed and depicted in Figure 7. The information below explains the inputs to the spreadsheet:

1. Enter ‘=SUMPRODUCT(\$B\$10:\$C\$10,B4:C4)’ in the target cell **D4** which evaluates the maximum profit.
2. Enter the constraint, ‘=SUMPRODUCT(\$B\$10:\$C\$10,B5:C5)’ for ‘Stamping department’ in **D5**.
3. Enter the slack, ‘=E5-D5’ for “Stamping department” in F5 as the objective function in this case is to maximize.
4. Repeat entering constraints and slacks for ‘Motor department’, ‘Washer Assembly’ and ‘Dryer assembly’ respectively in **D6, F6** and **D7, F7**.
5. Set decimal places to zero for cells **B10:C10, D4:D8** and **F5:F8**.
6. Go to Solver and Figure 8 will appear.
7. Enter target cell, changing cells and constraints as in the previous case.
8. Assume linear model and non-negative as in the previous case.

9. Solve the problem.

It can be found from Figure 9 that the maximum profit (cell **D4**) is \$946,667. Cells **B10** and **C10** show the number of washers (5,333) and dryers (4667) produced respectively. The surplus capacity for assembling washers (3667) and dryers (333) are also shown in cells **F7** and **F8** respectively.

Another software package used is *POM-QM for Windows 3*. In this package, users are only required to input the objective function and the constraints as in the case of solving the problem manually. There is no programming technique required as the package will do this automatically. Figure 10 shows the inputs and it is worth noting that the information in shaded area is automatically generated by the package. Figure 11 shows the simplex method results using *POM-QM for Windows 3*. It can calculate the number of washers and dryers produced as well as the maximum profit. Graphical results can also be shown as depicted in Figure 12.

In simplex method, the input to *POM-QM for Windows 3* is easier as it does not involve the re-structuring of the transportation table to simplex method equations. The input to *Excel* is the same as in the previous problem; some simple programming is required and again it is a minor challenge to engineering students.

### *Assessments*

At the moment, there were three assessments for the course, two assignments and one examination. Starting from Semester 2, 2008, the first assignment will deal with

critical path network analysis with a weighting of 15 %; the other one will be for distribution method or simplex method (programming techniques), simulation and control charts (quality control) respectively a weighting 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 is 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 [7].

In this paper, only part of the second assignment – programming techniques will be discussed. The distribution method question of assignment 2, Semester 3, 2008 describes that water is to be supplied from 3 dams to meet the demands in five regions in such a way as to minimize the pumping costs. Table 3 shows the amount of water available in the dams and the regional demands for water are expressed in gegalitres (GL/year). Students are required to determine the allocation of water that minimizes the yearly pumping cost and calculate the total minimum pumping cost for the year by (i) manual method in not less than 6 iterations and (ii) using *Excel in MS Office 2007* [students are required to submit their work for part (ii) in a CD-ROM].

It can be argued that students will solve the problem using *Excel* first to get a solution before doing it manually by iteration; the authors, therefore, requested students to do at least 6 iterations to ensure that they learn the process while doing this exercise; the authors' solution consisted of 10 iterations. To solve this problem, it is necessary to create one dummy region to balance supply and demand. The number of assigned squares must then be equal to  $m + n - 1 = 8$  in this case as depicted in Figure 13, which also shows the initial allocation of water from dams to regions in the upper matrix (highlighted). The pumping costs from dams to regions are shown in the lower (not highlighted) matrix in Figure 13. The total cost to effect this allocation is \$ 4,090,000. This is also shown in the squared (highlighted) box in Figure 13. After setting the target cells and constraints as in the case of Figure 1, the problem was solved using *Solver* and the results are illustrated in Figure 14. The minimum cost is \$2,450,000.

### ***Discussion***

The objectives of the module, programming techniques, consist of [8]:

1. identify the two models of programming and the types of problems associated with each.
2. solve simple problems relating to the various methods of linear programming.

Finally, it is the time to consider how the software packages satisfy the objectives of the module. Both *Excel* in *MS Office 2007* and *POM-QM for Window 3* are able to solve distribution problems and they are shown in Figures 1 to 4, and 5 to 6 respectively. Both packages can satisfy the distribution method of objective 2 of the

module; this meets the desired outcome as learners can distribute the pallets from departments with excess pallets to departments which require pallets in minimum time.

Both *Excel in MS Office 2007* and *POM-QM for Window 3* are able to solve simplex method problems and they are shown in Figures 7 to 9, and 10 to 11 respectively. These are in line with the desired outcomes as learners learn ways to solve simplex method problems, which is the second half of the objective 2 of the module.

As far as programming techniques in ENG 4004, *Engineering Management Science* are concerned; it appears to the authors that both packages can perform the work at par. The preliminary work for solving the transportation (distribution) problem using *Excel* is less; students can solve the problem by entering data to the spreadsheet as described earlier in this paper. The *Excel* programming required is minimal. On the other hand, if *POM-QM for Windows 3* is used to solve the transportation problem, one has to re-structure the problem to a simplex method equations; this is tedious and may involve a lot of variables as indicated earlier in this paper. Of course, after the re-structuring, the process will be simple; no programming will be required and data can be easily input into the template provided by the package.

For simplex method, *POM-QM for Windows 3* is good for beginners as the input to the template provided is very straight forward and if there are only two variables, a graphical solution will also be provided. However, the package may seem unchallenging to engineering students. With *Excel*, no graphical solution will be provided even for problems with two variables. However, it can deal with more than

two variables. The programming required is minimal as in the case of transportation problem.

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. Table 4 shows how scores were allocated to the software packages. As the total scores of *Excel in MS Office 2007* (26) is higher than that of *POM-QM for Windows 3* (23), the former is therefore considered to be a more suitable package for the module.

As the new form of assignments will require students to solve the programming techniques both manually as well as using the appropriate software packages, students will need to spend more time and hence more weighting should be assigned to assignments. It has been decided that the weightings for assignments 1 and 2 and open book examination will be 15%, 25 % and 60% respectively and this should start in Semester 2, 2009.

The addition of the 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 using standard software packages.

Iglesias and Paniagua used spreadsheets in an undergraduate course as a tool to solve optimization problems with iteration cycles in the calculation of the variables involved and as an introductory approach for the basic aspects of process simulators. They were able to appreciate the advantages of using a spreadsheet as work environment compared to other environments; it turned out to be more powerful than GAMS or MathCAD. Another important aspect is the possibility of incorporating new calculation procedures, in a simple and transparent way, to the user form. The readiness of a powerful programming language, such as VBA in the case of Excel, as well as the ease of recording, editing, and modifying macros notably simplifies the task of preparing material to be used in the course. It is advisable to use Solver to solve all iterations present in the problem, still those that can be automatically treated by the spreadsheet [8].

Kao investigated the performance of six nonlinear programming (NLP) packages, including MATLAB, IMSL, AMPL, GAMS, GINO, and SQP, by solving seventy test problems on a PC 486 machine. These packages were categorized as library subroutines, modelling languages, and the conventional NLP codes. The results showed that AMPL and GINO have the best ability in solving NLP problems optimally, GAMS was the most efficient package in terms of the execution time, GINO has the most accurate solution, and MATLAB needed the least effort in modelling problems. In sum, GAMS and GINO had the best overall performance, followed by AMPL. All these three packages are of modelling language type [9].

It can also be argued that other authors are also working in a similar way to the authors of this paper. The difference between their work and this is that they use

software packages to help teaching engineering courses other than engineering management science but all are enhancing their learning and teaching by using relevant software packages [10-14].

### ***Conclusion***

In the first paper in this series, the authors conclude that different software packages will be required to solve different parts of critical path network problems, i.e. cocktail software - *POM-QM for Windows 3* and *MS Project 2007* [5]. However, *POM-QM for Windows 3* was to be able to solve most parts of a problem and was preferred. However, in the second paper in the same series, it was discovered that *Excel in MS Office 2007* will do the required jobs more effectively. However, it can still be argued that *POM-QM for Windows 3* is also a suitable package for the course, i.e. both packages are suitable but *Excel in MS Office 2007* is preferred. Table 4 shows that both packages are unable to solve the problems of Objective 1. Both can solve the problems of distribution of Objective 2 but Excel can do the job better. As far as the simplex problems of Objective 2 are concerned, both can do the same equally. Their prices are equally friendly as Excel comes with MS Office2007 and POM-QM for Windows 3 comes with the text book. Overall, Excel is better and scored 26 as depicted in Table 4. This was also indicated by Iglesias and Paniagua [8].

Other free spreadsheet packages such as OpenOffice, Calc, Gnumeric and MATLAB can be argued to be able to perform what Excel in MS Office 2007 can perform in this study. Google Docs, a spreadsheet or similar online 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.

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	A	B	C	D	E	F	G	H	I
1	Pallets Distribution								
2									
3									
4	Units moved				To				
5			W	X	Y	Z	Total moved		
6	From	A	7	1	0	0	8	<=	8
7		B	0	9	4	0	13	<=	13
8		C			2	9	11	<=	11
9		Total allocated	7	10	6	9			
10			>=	>=	>=	>=			
11			7	10	6	9			
12		Total time	475						
13									
14									
15	Moving distance								
16					To				
17			W	X	Y	Z			
18		A	10	22	10	20			
19	From	B	15	20	12	8			
20		C	20	12	10	15			

Figure 1: Spreadsheet model for problem with information from Table 2

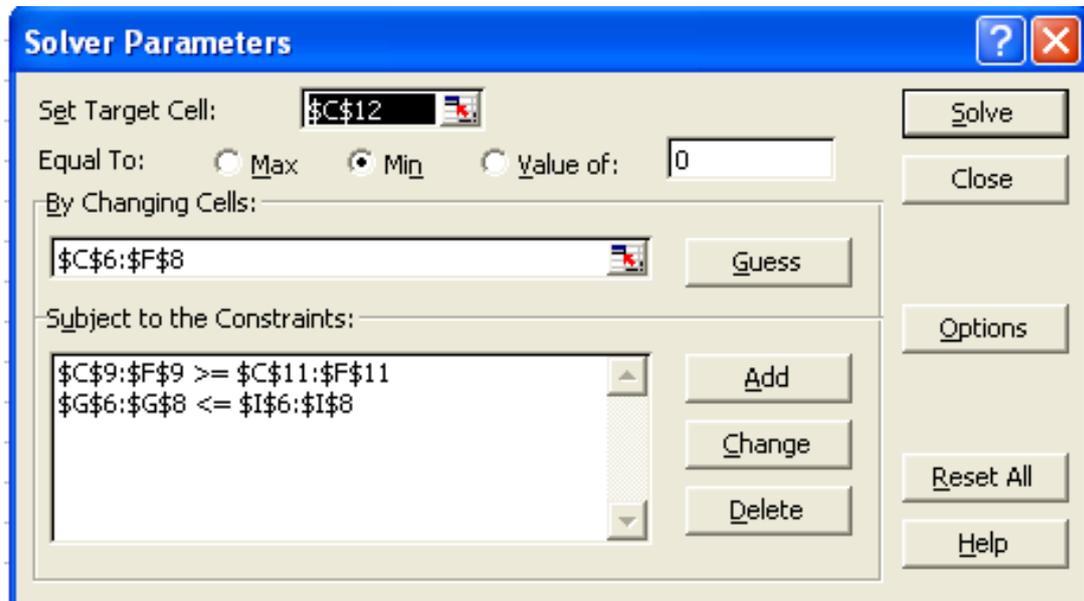


Figure 2: Solver screen

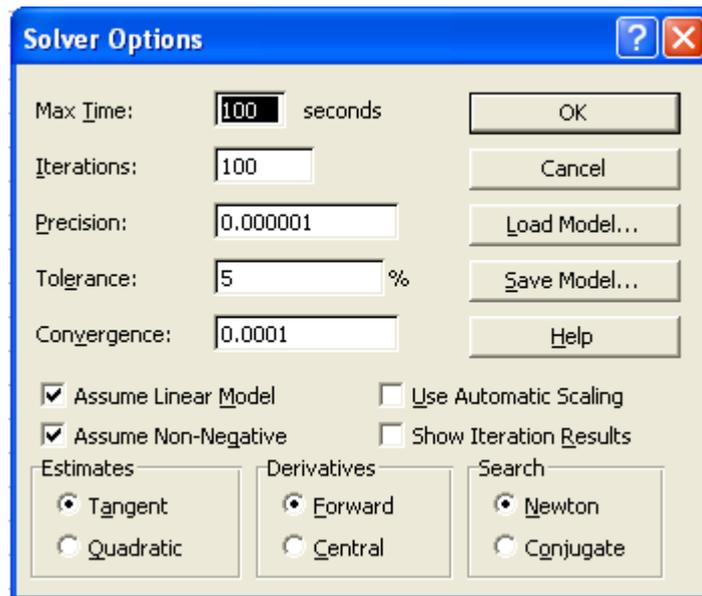


Figure 3: Option's screen

	A	B	C	D	E	F	G	H	I	J
1	Pallets Distribution									
2										
3										
4	Units moved			To						
5			W	X	Y	Z	Total moved			
6	From	A	7	0	1	0	8	<=	8	
7		B	0	0	4	9	13	<=	13	
8		C	0	10	1	0	11	<=	11	
9		Total allocated	7	10	6	9				
10			>=	>=	>=	>=				
11			7	10	6	9				
12		Total time	330							
13										
14										
15	Moving distance									
16										
17			W	X	Y	Z				
18		A	10	22	10	20				
19	From	B	15	20	12	8				
20		C	20	12	10	15				
21	<div style="border: 1px solid black; padding: 5px;"> <p><b>Solver Results</b></p> <p>Solver found a solution. All constraints and optimality conditions are satisfied.</p> <p> <input checked="" type="radio"/> Keep Solver Solution  <input type="radio"/> Restore Original Values         </p> <p>Reports: Answer, Sensitivity, Limits</p> <p> <input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Save Scenario..."/> <input type="button" value="Help"/> </p> </div>									
22										
23										
24										
25										
26										
27										
28										
29										
30										

Figure 4: Solution's screen

Objective		Instruction												
<input type="radio"/> Maximize		Enter the value for minimize for v(cx). For example, if the inequality is $x_1 + 2x_2 \leq 3$ then enter 1 in the column for $x_1$ and 2 in the column for $x_2$ . Enter the value for the right hand side of the constraint.												
<input checked="" type="radio"/> Minimize														
Example														
	V(AW)	V(AX)	V(AY)	V(AZ)	V(BW)	V(BX)	V(BY)	V(BZ)	V(CW)	V(CX)	V(CY)	V(CZ)	RHS	Equation form
Minimize	10	22	10	20	15	20	12	8	20	12	10	15		Min 10V(AW) +
Pallets fr A	1	1	1	1	0	0	0	0	0	0	0	0	8	$V(AW) + V(AX) +$
Pallets fr B	0	0	0	0	1	1	1	1	0	0	0	0	13	$V(BW) + V(BX) +$
Pallets fr C	0	0	0	0	0	0	0	0	1	1	1	1	11	$V(CW) + V(CX) +$
Pallets to W	1	0	0	0	1	0	0	0	1	0	0	0	7	$V(AW) + V(BW) +$
Pallets to X	0	1	0	0	0	1	0	0	0	1	0	0	10	$V(AX) + V(BX) +$
Pallets to Y	0	0	1	0	0	0	1	0	0	0	1	0	6	$V(AY) + V(BY) +$
Pallets to Z	0	0	0	1	0	0	0	1	0	0	0	1	9	$V(AZ) + V(BZ) +$

Figure 5: Format of inputs required by the package

Linear Programming Results						
Example Solution						
	V(AW)	V(AX)	V(AY)	V(AZ)	V(BW)	V(BX)
Minimize	10	22	10	20	15	20
Pallets fr A	1	1	1	1	0	0
Pallets fr B	0	0	0	0	1	1
Pallets fr C	0	0	0	0	0	0
Pallets to W	1	0	0	0	1	0
Pallets to X	0	1	0	0	0	1
Pallets to Y	0	0	1	0	0	0
Pallets to Z	0	0	0	1	0	0
Solution->	7	0	1	0	0	0

Example Solution								
V(BY)	V(BZ)	V(CW)	V(CX)	V(CY)	V(CZ)	RHS	Dual	
12	8	20	12	10	15			
0	0	0	0	0	0	8	2	
1	1	0	0	0	0	13	0	
0	0	1	1	1	1	11	2	
0	0	1	0	0	0	7	-12	
0	0	0	1	0	0	10	-14	
1	0	0	0	1	0	6	-12	
0	1	0	0	0	1	9	-8	
4	9	0	10	1	0	330		

Figure 6: Results of the simplex method

	A	B	C	D	E	F
1	Washing machines					
2						
3		washers	dryers			
4	Objective function	90	100			0
5	Stamping department	1	1		10000	10000
6	Motor department	1	2	2/7	0	16000
7	Washer assembly		1	0	0	9000
8	Dryer assembly		0	1	0	5000
9						
10			0	0		

Figure 7: Using Excel to solve simplex problems

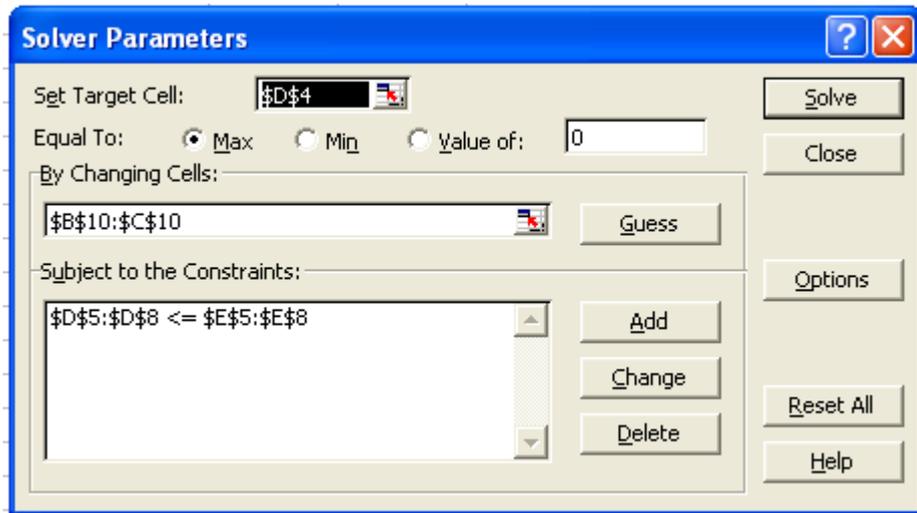


Figure 8: Solver screen

	A	B	C	D	E	F
1	Washing machines					
2						
3		washers	dryers			
4	Objective function	90	100	946667		
5	Stamping department	1	1	10000	10000	10000
6	Motor department	1	2 2/7	16000	16000	0
7	Washer assembly	1	0	5333	9000	3667
8	Dryer assembly	0	1	4667	5000	333
9						
10		5333	4667			

Solver Results	
Solver found a solution. All constraints and optimality conditions are satisfied.	
<input checked="" type="radio"/> Keep Solver Solution	Reports
<input type="radio"/> Restore Original Values	Answer
	Sensitivity
	Limits
OK	Cancel
Save Scenario...	Help

Figure 9: Solution's screen

POM-QM for Windows - C:\POMQM\3\Examples\Washer & dryer.basic.LIN - [Data Table]

File Edit View Module Format Tools Window Help

Objective  
 Maximize  
 Minimize

Instruction  
 Enter the value for motor department for rhs. Any non-negative value is permissible.

Example

	Washer	Dryers		RHS	Equation form
Maximize	90	100			Max 90Washer + 100Dryers
Stamping department	1	1	<=	10,000	Washer + Dryers <= 10000
Motor department	1	2.286	<=	16,000	Washer + 2.2857Dryers <=
Washer assembly	1		<=	9,000	Washer <= 9000
Dyer assembly		1	<=	5,000	Dryers <= 5000

Figure 10: Objective function and constraints

Linear Programming Results

Example Solution

	Washer	Dryers		RHS	Dual
Maximize	90	100			
Stamping department	1	1	<=	10,000	82.222
Motor department	1	2.286	<=	16,000	7.778
Washer assembly	1		<=	9,000	0
Dyer assembly		1	<=	5,000	0
Solution->	5,333.282	4,666.718		946,667.2	

Dual

Example Solution

	Stamping	Motor	Washer	Dyer assembly		
<b>Original Problem</b>						
Maximize	Washer	Dryers				
Stamping department	1	1	<=	10000		
Motor department	1	2.2857	<=	16000		
Washer assembly	1		<=	9000		
Dyer assembly		1	<=	5000		
<b>Dual Problem</b>						
Minimize	10000	16000	9000	5000		
Washer	1	1	1	0	>=	90
Dryers	1	2.2857	0	1	>=	100

Figure 11: Simplex method results

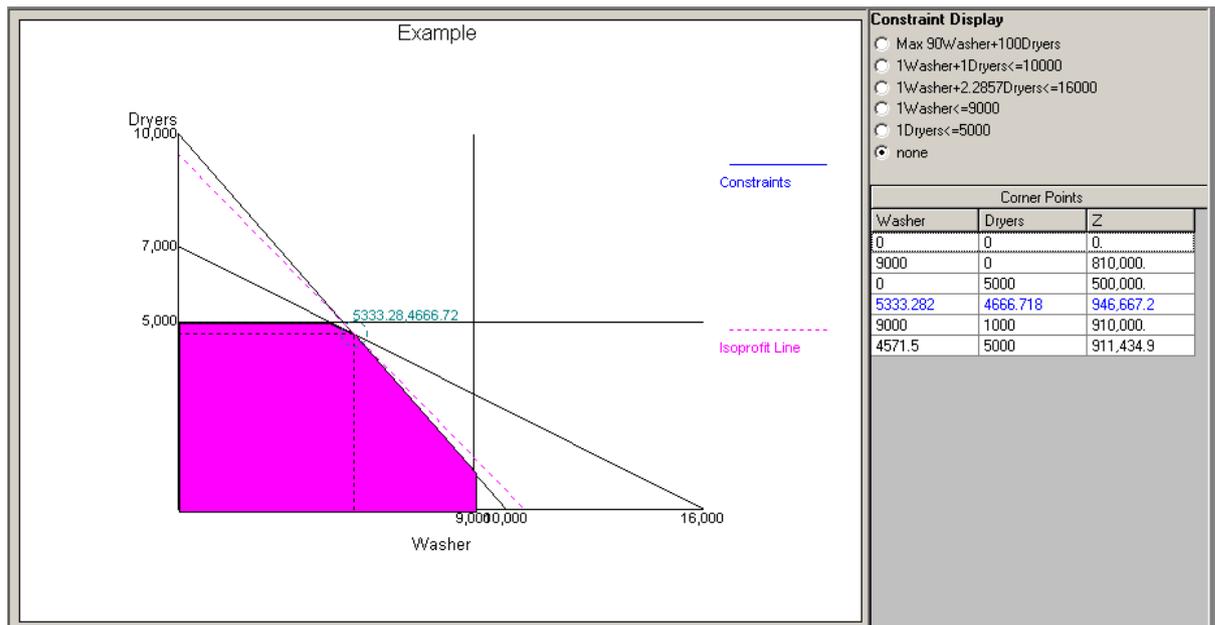


Figure 12: Graphical results of simplex methods

	A	B	C	D	E	F	G	H	I	J	
1	Dam distribution problem, ENG 4004_08_3										
2								Water			
3			Regions					available			
4	Dams	1	2	3	4	5	Dummy				
5	A	60	20	0	0	0	0	80 <=		80	
6	B	0	20	100	20	0	0	140 <=		140	
7	C	0	0	0	50	70	40	160 <=		160	
8		60	40	100	70	70	40				
9		>=	>=	>=	>=	>=	>=				
10	Water pumped	60	40	100	70	70	40				
11	Total costs	4090									
12											
13	Pumping cost	Regions									
14		1	2	3	4	5	Dummy				
15	A	11	20	3	5	15	100				
16	B	4	16	10	19	8	100				
17	C	12	7	23	14	9	100				

Figure 13: Spreadsheet model for the dam supply problem

	A	B	C	D	E	F	G	H	I	J	
1	Dam distribution problem, ENG 4004_08_3										
2								Water			
3			Regions					available			
4	Dams	1	2	3	4	5	Dummy				
5	A	0	0	20	60	0	0	80	<=	80	
6	B	60	0	80	0	0	0	140	<=	140	
7	C	0	40	0	10	70	40	160	<=	160	
8		60	40	100	70	70	40				
9		>=	>=	>=	>=	>=	>=				
10	Water pumped	60	40	100	70	70	40				
11	Total costs	2450									
12											
13	Pumping cost		Regions								
14		1	2	3	4	5	Dummy				
15	A	11	20	3	5	15	100				
16	B	4	16	10	19	8	100				
17	C	12	7	23	14	9	100				

Figure 14: Solution screen for Figure 15

**Table 1: Topics in ENG4004**

TOPICS
1. Critical path networks,
2. Programming techniques
3. Simulation
4. Quality control
5. Micro-economic functions

**Table 2: Initial matrix indicating the initial problem**

From \ To	W	X	Y	Z	Pallets Available
A		22	10	20	8
B					13
C	10				11
Pallets required	7	10	6	9	32
	15	20	12	8	
	20	12	10	15	

**Table 3: Water available in 3 dams and demand from 5 regions**

Dam	Pumping Cost (\$1000s/GL)					Water Available (GL/year)
	Region					
	1	2	3	4	5	
A	11	20	3	5	15	80
B	4	16	10	19	8	140
C	12	7	23	14	9	160
<b>Demand (GL/year)</b>	60	40	100	70	70	

**Table 4: Scores to the two software packages used**

Factors considered	Software Packages	
	<i>POM-QM for Windows 3</i>	<i>Excel in MS Office 2007</i>
Objective 1	0	0
Objective 2 – distribution method	5	8
Objective 2 – simplex method	8	8
Price	10	10
Total scores	23	26