Operations Analysis

BEMM462

PROJECT: 01

(A) For this project, we will consider 2 inputs and 1 output. Inputs are Person-days and CPU time (hours) and Profit (in million £) as output. After all, every firm's end result is profit as if the person will work on each project then only they can get some outputs. After undertaking these inputs and outputs which have to be optimized, we got the efficient and inefficient projects correctly.

(B) After selecting the correct inputs and outputs, they should be valued in such a manner that the firm should look different from any other firm. To determine, among the 8 projects which project is most efficient, we will check the efficiency of each project. Efficiency can be determined by the given formula:

$$\text{Efficiency of projects} = \frac{\text{Values of outputs of the projects}}{\text{Values of inputs of the projects}}$$

None of the projects can be efficient more than 100%, therefore the efficiency of each project is constrained to less than equal to 1.

<u>Value of input of the project ≥ Value of outputs of the project</u>

By the given inputs and outputs, we have created a spreadsheet model for analysing Data Envelopment Analysis. Before analysing, we are using the BCC (Bankers-Charnes -Cooper) type of DEA model which is used at the point when a variable returns to scale relationship is expected among inputs and outputs. We will be analysing the given model to check the efficiency of each project. The spreadsheet model is shown below:

	A	B	C	D	E	F
1	DEA Model for checking efficiency of a engineering consultancy firm					
2						
3	Selecting Project	1				
4						
5	Input used	Input 1 (Person-days)	Input 2 (CPU time)		Output produced	Output 1 (Profit million £)
6	Project 1	550	200		Project 1	2.1
7	Project 2	400	150		Project 2	0.5
8	Project 3	300	400		Project 3	3
9	Project 4	350	450		Project 4	2
10	Project 5	450	300		Project 5	1
11	Project 6	500	150		Project 6	1.5
12	Project 7	350	200		Project 7	0.6
13	Project 8	200	600		Project 8	1.8
14						
15	Inputs (decision variable)	0.003	0.005		Outputs (decision variable)	0.01
16						
17	Inputs covering outputs values					
18	Project	Inputs		Outputs		
19	1	2.65	>=	0.021		
20	2	1.95	>=	0.005		
21	3	2.9	>=	0.03		
22	4	3.3	>=	0.02		
23	5	2.25	>=	0.01		
24	6	2.25	>=	0.015		
25	7	2.05	>=	0.006		
26	8	3.6	>=	0.018		
27						
28	Inputs must be equal to nominal value of 1					
29	Selected project input	2.65	=	1		
30						
31	Maximize selected project's output value (to see if it is 1, hence efficient)					
32	Selected projet output value	0.021				

Fig.01: DEA Model before Solver

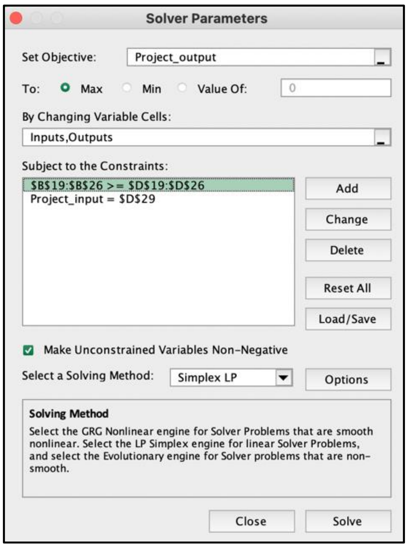
"Inputs unit price decision" is the decision variable and it will keep changing according to different projects, so at the initial level, we have assumed the values for inputs and output. Before, we mentioned inputs should be more than equal to outputs. We got the values of inputs and outputs from the formula:

=SUMPRODUCT(Inputs,Input_project1)
=SUMPRODUCT(Outputs,Output_project1)

Similarly, we calculated the values of all 8 projects. Further, we calculated the total inputs and outputs of the selected project by the below function:

=VLOOKUP(Selecting_project,A19:B26,2)
=VLOOKUP(Selecting_project,A19:D26,4)

Afterwards, we will use Excel Solver to determine which project is efficient and which is inefficient by setting our objective to the maximum to get efficiency as 1. Choose inputs and outputs as decision variables and constraints as shown in the figure below. Efficiency constraints are the main constraint which will ensure our inputs should be greater than or equal to outputs.



G	H
Range Names Used	
Input_project1	=Sheet2!$B$6:$C$6
Input_project2	=Sheet2!$B$7:$C$7
Input_project3	=Sheet2!$B$8:$C$8
Input_project4	=Sheet2!$B$9:$C$9
Input_project5	=Sheet2!$B$10:$C$10
Input_project6	=Sheet2!$B$11:$C$11
Input_project7	=Sheet2!$B$12:$C$12
Input_project8	=Sheet2!$B$13:$C$13
Inputs	=Sheet2!$B$15:$C$15
Output_project1	=Sheet2!$F$6
Output_project2	=Sheet2!$F$7
Output_project3	=Sheet2!$F$8
Output_project4	=Sheet2!$F$9
Output_project5	=Sheet2!$F$10
Output_project6	=Sheet2!$F$11
Output_project7	=Sheet2!$F$12
Output_project8	=Sheet2!$F$13
Outputs	=Sheet2!$F$15
Project_input	=Sheet2!$B$29
Project_output	=Sheet2!$B$32
Selecting_project	=Sheet2!$B$3

After using Excel Solver, we will get the results for Project 1 which has the output value 1 which means Project 1 is efficient and can be perused by the directors/partners of the firm. Result of the project 1 is:

	A	B	C	D	E	F
1	**DEA Model for checking efficiency of a engineering consultancy firm**					
2						
3	**Selecting Project**	1				
4						
5	**Input used**	**Input 1 (Person-days)**	**Input 2 (CPU time)**		**Output produced**	**Output 1 (Profit million £)**
6	Project 1	550	200		Project 1	2.1
7	Project 2	400	150		Project 2	0.5
8	Project 3	300	400		Project 3	3
9	Project 4	350	450		Project 4	2
10	Project 5	450	300		Project 5	1
11	Project 6	500	150		Project 6	1.5
12	Project 7	350	200		Project 7	0.6
13	Project 8	200	600		Project 8	1.8
14						
15	**Inputs (decision variable)**	0.000714286	0.003035714		**Outputs (decision variable)**	0.476190476
16						
17	**Inputs covering outputs values**					
18	**Project**	**Inputs**		**Outputs**		
19	1	1	>=	1		
20	2	0.741071429	>=	0.238095238		
21	3	1.428571429	>=	1.428571429		
22	4	1.616071429	>=	0.952380952		
23	5	0.8125	>=	0.476190476		
24	6	0.8125	>=	0.714285714		
25	7	0.857142857	>=	0.285714286		
26	8	1.964285714	>=	0.857142857		
27						
28	**Inputs must be equal to nominal value of 1**					
29	Selected project input	1	=	1		
30						
31	**Maximize selected project's output value (to see if it is 1, hence efficient)**					
32	Selected projet output value	1				

Fig.02: DEA Model after Analyzing

Similarly, we can do all 8 projects. We can change the "Selecting_project" cell (B3) and get the efficiency of all 8 projects.

An alternate way to check the efficiency altogether of 8 Projects is to calculate in R Studio. We have executed the function of checking efficiency while inserting inputs and outputs.

```
Untitled2* ×
Source on Save                                   Run
library(rDEA)
X <- data.frame("Person-days" =c(550,
                                 400,
                                 300,
                                 350,
                                 450,
                                 500,
                                 350,
                                 200),
                "CPU time(hrs)" = c(200,
                                 150,
                                 400,
                                 450,
                                 300,
                                 150,
                                 200,
                                 600))
```

```
Y <- data.frame("Profit(in million £)" =c(2.1,
                                           0.5,
                                           3,
                                           2,
                                           1,
                                           1.5,
                                           0.6,
                                           1.8))
## Naive input-oriented DEA score for the 8 projects under variable
##returns-to-scale
projects=1:8
di_naive = dea(XREF=X, YREF=Y, X=X[projects,], Y=Y[projects,], model="input",
               RTS="constant")
di_naive$thetaOpt
```

Fig.03,04: Inputs and Outputs of DEA Model in R Studio

By, executing the above function we get the following results which will show the efficiency of all the eight projects in sequence:

```
> projects=1:8
> di_naive = dea(XREF=X, YREF=Y, X=X[projects,], Y=Y[projects,], model="input",
+               RTS="constant")
> di_naive$thetaOpt
[1] 1.0000000 0.3212851 1.0000000 0.5893186 0.3864734 0.9523810 0.3333333 0.9000000
> 
```

Fig.05: Efficiency of projects

We can clearly see that projects 1 and project 3 are the most efficient and project two is inefficient. And if go from efficient to inefficient projects respectively, the sequence will be in Project 1, Project 3, Project 6, Project 8, Project 4, Project 5, Project 7, and Project 2.

(C) We would recommend Project 3 as it is providing us with the maximum profit (output) out of other projects with minimum inputs and Project 1 with the profit of £2.1 million with fewer inputs. Two projects we would recommend the directors and their partners prioritize among the eight projects.

(D) To improve the recommendation, we're adding one input column and one output column to check the efficiency.

	A	B	C	D	E	F	G
1	**DEA Model for checking efficiency of a engineering consultancy firm**						
2							
3	**Selecting Project**	1					
4							
5	**Input used**	**Input 1 (Person-days)**	**Input 2 (CPU time)**	**Input 3 (Direct Cost)**	**Output produced**	**Output 1 (Profit million £)**	**Output 2**
6	Project 1	550	200	100	Project 1	2.1	0.5
7	Project 2	400	150	300	Project 2	0.5	1.5
8	Project 3	300	400	200	Project 3	3	1.7
9	Project 4	350	450	250	Project 4	2	2
10	Project 5	450	300	340	Project 5	1	4
11	Project 6	500	150	410	Project 6	1.5	3
12	Project 7	350	200	240	Project 7	0.6	2.5
13	Project 8	200	600	170	Project 8	1.8	1.9
14							
15	**Inputs (decision variable)**	0.003	0.004	0.005	**Outputs (decision variable)**	0.01	0.03

Fig.06: DEA Model after additional Input and Output

To get the efficiency of all 8 project, we'll use R Studio the same as before:

```
> projects=1:8
> di_naive = dea(XREF=X, YREF=Y, X=X[projects,], Y=Y[projects,], model="input",
+                RTS="constant")
> di_naive$thetaOpt
[1] 1.0000000 0.5901639 1.0000000 0.7967296 1.0000000 1.0000000 0.9183673 1.0000000
> 
```

Fig.07: Efficiency of DEA Model

Projects	Efficiency	Efficient/Inefficient
Project 1	1.00	Efficient
Project 2	0.59	Inefficient
Project 3	1.00	Efficient
Project 4	0.79	Inefficient
Project 5	1.00	Efficient
Project 6	1.00	Efficient
Project 7	0.91	Inefficient
Project 8	1.00	Efficient

We can see from the above table, that there are 5 projects which are efficient after adding new inputs and outputs, before that it was 2.

(E) If we take two different industries for the analysis, we can analyze it with some similar data. For example, if we are taking the agricultural industry and iron industry, manufacturing time and agriculture growth timing; investment in both the industries; also transit time of raw material to reach the end user. If we gather those data, we can analyze it since the inputs are the same. Approve Analytical Model in a particular industry can be applied to other industry using similar inputs.

PROJECT: 02

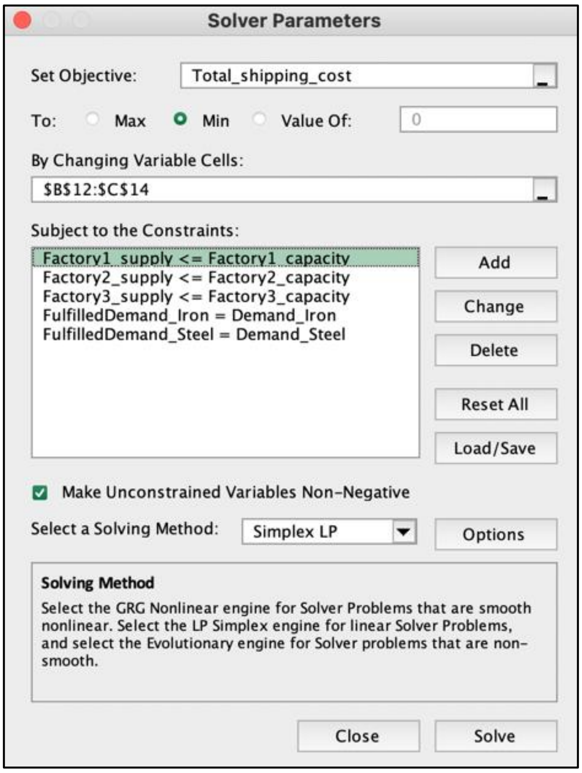
(A) By undertaking all the factors of the company which has 3 factories which produce steel and iron, we came up with a spreadsheet model step by step which has integrated different data from multiple tables(factors). Following is the spreadsheet model of the company:

	A	B	C	D	E	F
1	**To determine the optimal monthly plan:**					
2		**Steel**	**Iron**			
3	**Demand**	3200	1000			
4						
5		**Steel**	**Iron**		**Capacity in factory's warehouse**	
6	**Shipping Cost (£/tonne)**					**Capacity**
7	**Factory 1**	200	500		**Factory 1**	2000
8	**Factory 2**	800	400		**Factory 2**	1500
9	**Factory 3**	500	1000		**Factory 3**	2500

Fig.08: Spreadsheet Model

Our initial objective is to determine the optimal monthly plan to find how many tonnes each factory needs to ship to fulfil the demand.

For analyzing the optimal solution, we will be using Excel Solver for this table to get solution. Initially, we have to set our objective and mention our decision variable as the solver will adjust the values to satisfy demand. Also, there are some constraints such as the demand for steel and iron and many more (mentioned in the solver dialog box) which are important to mention and sure to use the Simplex LP method which is used to solve Linear Programming. Taking all these factors into consideration, below is the solver box by which we will be obtaining our objective.



G	H
Range Names Used	
Demand_Iron	='Sheet 1'!$C$16
Demand_Steel	='Sheet 1'!$B$16
Factory1_capacity	='Sheet 1'!$E$12
Factory1_supply	='Sheet 1'!$D$12
Factory2_capacity	='Sheet 1'!$E$13
Factory2_supply	='Sheet 1'!$D$13
Factory3_capacity	='Sheet 1'!$E$14
Factory3_supply	='Sheet 1'!$D$14
FulfilledDemand_Iron	='Sheet 1'!$C$17
FulfilledDemand_Steel	='Sheet 1'!$B$17
Total_shipping_cost	='Sheet 1'!$B$19

	A	B	C	D	E	F
5		Steel	Iron		Capacity in factory's warehouse	
6	Shipping Cost (£/tonne)					Capacity
7	Factory 1	200	500		Factory 1	2000
8	Factory 2	800	400		Factory 2	1500
9	Factory 3	500	1000		Factory 3	2500
10						
11		Steel	Iron	Supply	Capacity	
12	Factory 1	2000	0	2000	2000	
13	Factory 2	0	1000	1000	1500	
14	Factory 3	1200	0	1200	2500	
15						
16	Demand	3200	1000			
17	Fulfilled Demand	3200	1000			
18						
19	Total Shipping Cost	1400000				

Fig.09: Spreadsheet Model after analyzing

We got the optimal solution for the company, fulfilling the demand with the supply of each factory. So, if we supply **2000 tonnes** of steel to **Factory 1** which also consumes all its capacity of it, **1000 tonnes** of iron to **Factory 2** and the remaining **1200 tonnes** of steel to **Factory 3** it will cost **£14,00,000**.
If we go according to this plan, we can meet the demand with the minimum cost and consume most of the capacity.

(B) Suppose if we remove Factory 3, the total capacity will reduce by 2500 and keeping the total demand same i.e., 4200 **Demand > Capacity**, if capacity is less (i.e., 3500), the company won't be able to supply enough steel and iron to fulfil the demand for few months.

	A	B	C	D	E
1	To determine the optimal monthly plan:				
2		Steel	Iron	Total Demand	
3	Demand	3200	1000	4200	
4					
5		Steel	Iron	Capacity in factory's warehouse	
6	Shipping Cost (£/tonne)				Capacity
7	Factory 1	200	500	Factory 1	2000
8	Factory 2	800	400	Factory 2	1500
9				Total Capacity	3500

If we're unable to fulfil the demand, a Revised assignment plan can be the supervised model, we can take all important relations and constraints which can permit the current framework to select start and end combinations. Also, we use the penalty objective, which is total discounted penalty pounds with unavailability penalties to accomplish the task executed.

(C) After including the cost of raw materials of the company, we have created a new spreadsheet model with the new costs being the demand same as before is shown below:

	A	B	C	D	E	F
4	To determine minimum optimal monthly plan with cost of raw material:					
5		Steel	Iron		Capacity in factory's warehouse	
6	Shipping Cost (£/tonne)					Capacity
7	Factory 1	200	500		Factory 1	2000
8	Factory 2	800	400		Factory 2	1500
9	Factory 3	500	1000		Factory 3	2500
10						
11		Steel	Iron	Supply	Capacity	
12	Factory 1	2000	0	2000	2000	
13	Factory 2	0	1000	1000	1500	
14	Factory 3	1200	0	1200	2500	
15		Steel	Iron			
16	Raw Material Cost (£/tonne)					
17	Factory 1	50	100			
18	Factory 2	70	120			
19	Factory 3	45	130			
20						
21	Demand	3200	1000			

Fig.10: Spreadsheet Model with raw materials

We'll use the total shipping cost which we calculated in part (a) using a solver. Afterwards, the Cost of Raw Materials can be calculated from the given formula:

=SUMPRODUCT(Raw_material,Steel_iron_supply)

The above formula will automatically provide us with the minimum cost of raw material as we used a solver to calculate the minimum total shipping cost and we're using that steel iron supply (B12:C14) which will provide us with the minimum cost of raw material.
After using the formula, the Cost of Raw Material will be £2,74,000. We have to calculate the total cost, which is calculated from the formula below:

=SUM(Total_shipping_cost:Raw_material_cost)

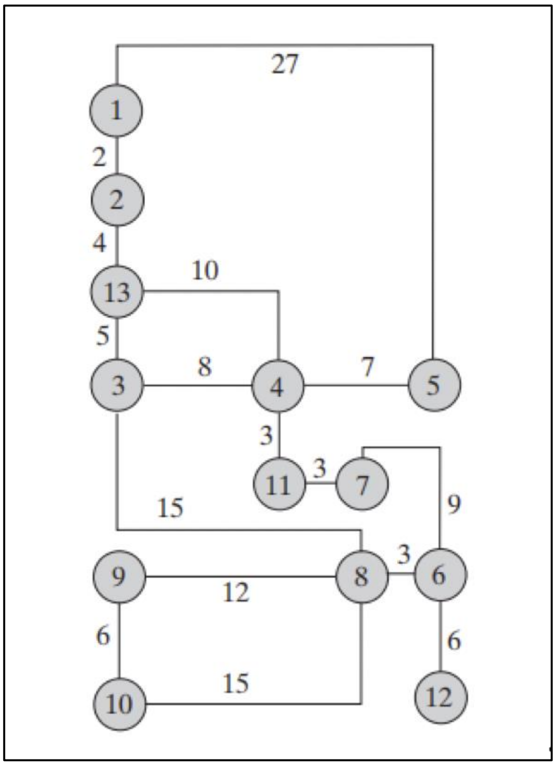
G	H
Range Names Used	
Iron_demand	=Sheet3!$C$21
Raw_material	=Sheet3!$B$17:$C$19
Raw_material_cost	=Sheet3!$B$25
Steel_demand	=Sheet3!$B$21
Steel_iron_supply	=Sheet3!$B$12:$C$14
Total_cost	=Sheet3!$B$26
Total_shipping_cost	=Sheet3!$B$24

16	**Raw Material Cost (£/tonne)**		
17	**Factory 1**	50	100
18	**Factory 2**	70	120
19	**Factory 3**	45	130
20			
21	**Demand**	3200	1000
22	**Fulfilled Demand**	3200	1000
23			
24	**Total Shipping Cost**	£14,00,000	
25	**Raw Material Cost**	£2,74,000	
26	**Total Cost**	£16,74,000	

Overall, the optimal assignment plan will be, if the company wants to fulfil the demand of 3200 tonnes of Steel and 1000 tonnes of Iron in the given capacity of the warehouse, the minimum cost will be £16,74,000 which includes a shipping cost of £14,00,000 and £2,74,000 for the cost of raw material.
This solution will not change from the base solution as the constraints and the decision variables are the same before after including the cost of raw material.

PROJECT: 03

(A) Here, we have different social media influencers who are investing in promoting links between influencers. One of our clients, a digital advertising firm, needs to maintain connections between different influencers. In this case, they want a connection between influencer 1 to influencer 12. From each influencer to another, there is an investment cost, so, we would recommend selecting the shortest path from influencer 1 to influencer 12 so that they don't have to spend more cost. For that, we have created a Shortest Path Model, which will tell our clients the minimum cost they have to spend and the shortest path.
Before that, we have to create a basic structure of the model from the given flow chart:



	A	B	C
4	**Origin**	**Destination**	**Investment**
5	1	2	2
6	1	5	27
7	2	13	4
8	13	3	5
9	13	4	10
10	3	4	8
11	3	8	15
12	5	4	7
13	4	11	3
14	11	7	3
15	7	6	9
16	8	6	3
17	6	12	6
18	8	9	12
19	8	10	15
20	9	10	6

Afterwards, we created a new table of "Flow Balance Constraints" which includes the nodes, net outflow and required net outflow. Nodes are nothing but several nodes included. Required Net Outflow shows the flow of influencers like our customer wants a connection between influencers 1 to 12, so, we put 1 in front of node 1(origin) and -1 in front of node 12(destination).

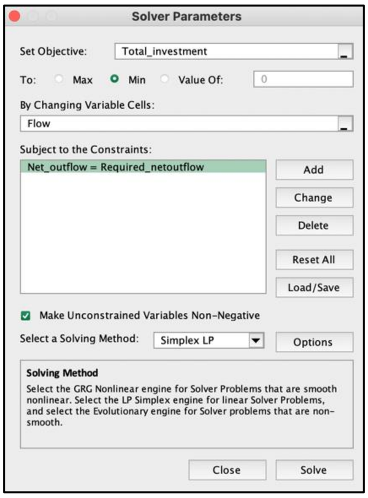
Initially, we have to keep the Flow Column empty. To calculate the Net Outflow, we are using the formula mentioned below:

=SUMIF(Origin,F5,Flow)-SUMIF(Destination,F5,Flow)

Later, we'll create our objective function by implementing the formula:

=SUMPRODUCT(Investment,Flow).

Using Solver, selecting our result cell and minimizing the cost. Choosing the flow table as a variable cell and adding the constraints as net outflow = required net outflow. After solving it with Simplex LP, we'll get the following results:



	A	B	C	D	E	F	G	H	I	J
1	**Shortest Path Model from Influencer 1 to Influencer 12**									
2										
3	**Network Structure and Flow**					**Flow Balance Constraints**				
4	**Origin**	**Destination**	**Investment**	**Flow**		**Node**	**Net Outflow**		**Required Net Outflow**	
5	1	2	2	1		1	1	=	1	
6	1	5	27	0		2	0	=	0	
7	2	13	4	1		3	0	=	0	
8	13	3	5	1		4	0	=	0	
9	13	4	10	0		5	0	=	0	
10	3	4	8	0		6	0	=	0	
11	3	8	15	1		7	0	=	0	
12	5	4	7	0		8	0	=	0	
13	4	11	3	0		9	0	=	0	
14	11	7	3	0		10	0	=	0	
15	7	6	9	0		11	0	=	0	
16	8	6	3	1		12	-1	=	-1	
17	6	12	6	1		13	0	=	0	
18	8	9	12	0						
19	8	10	15	0						
20	9	10	6	0						
21										
22	**Objective to minimize**									
23	**Total Investment**	35								

Fig.11: Spreadsheet Model

From the above results, we would recommend our client to choose the path starting from 1 to 2, then 2 to 13, next 13 to 3, 3 to 8, then 8 to 6, and finally from 6 to 12. If they choose this route, they have to invest the minimum amount i.e., 35.

(B) In the second part, our objective is to maximize the profit by completing different projects. We have to change the attributes to create a spreadsheet model.

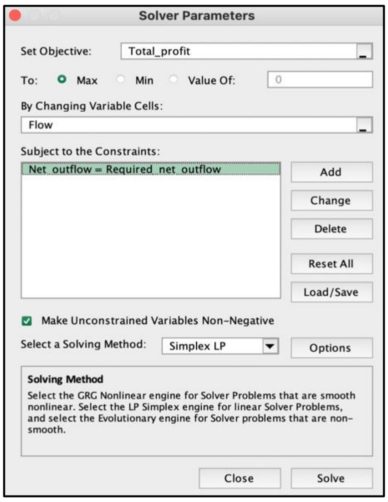
We will be using the same formula to calculate the Net Outflow:

=SUMIF(Origin,F5,Flow)-SUMIF(Destination,F5,Flow)

And to calculate the objective function we'll be using:

=SUMPRODUCT(Profit,Flow)

Using a solver in the same cell, we will be setting our objective(profit) to the max to get the maximum profit. Changing variable will be the Flow table as it will show us the route projects. Further, we will be adding constraints which will provide us with the solution based on it which net outflow should be equal to the required net outflow. Following is the solver dialog box:



L	M	N
Range Names Used		
Destination	=Sheet1!$B$5:$B$20	
Profit	=Sheet1!$C$5:$C$20	
Flow	=Sheet1!$D$5:$D$20	
Net_outflow	=Sheet1!$G$5:$G$17	
Node	=Sheet1!$F$5:$F$17	
Origin	=Sheet1!$A$5:$A$20	
Required_netoutflow	=Sheet1!$I$5:$I$17	
Total_profit	=Sheet1!$B$23	

	A	B	C	D	E	F	G	H	I	J
1	**Maximise Path Model from Influencer 1 to Influencer 12**									
2										
3	**Network Structure and Flow**					**Flow Balance Constraints**				
4	**Origin**	**Destination**	**Profit (million £)**	**Flow**		**Node**	**Net Outflow**		**Required Net Outflow**	
5	1	2	2	1		1	0	=	0	
6	5	1	27	1		2	0	=	0	
7	2	13	4	1		3	0	=	0	
8	13	3	5	1		4	0	=	0	
9	13	4	10	0		5	0	=	0	
10	3	4	8	0		6	0	=	0	
11	3	8	15	1		7	0	=	0	
12	4	5	7	1		8	0	=	0	
13	11	4	3	1		9	-1	=	-1	
14	7	11	3	1		10	0	=	0	
15	6	7	9	1		11	0	=	0	
16	8	6	3	0		12	1	=	1	
17	12	6	6	1		13	0	=	0	
18	9	8	12	0						
19	8	10	15	1						
20	10	9	6	1						
21										
22	**Objective to maximise**									
23	**Total Profit**	102								

After using the solver dialog box, we will be getting our results. The ideal sequence of completing projects and gaining the maximum profit out of them is starting from project 12 to 6, from 6 to 7, then 7 to 11, next 11 to 4, then 4 to 5, 5 to 1, 1 to 2, 2 to 13, 13 to 3, then 3 to 8, 8 to 10 and finally from 10 to 9. After, completing project 12 and starting from project 6, the firm will earn a profit of £6 million. Similarly, if they follow the mentioned path of completing projects, at the end of project 9, the firm will earn a profit of £102 million.

(C) A few of the Shortest path problems and Maximum flow problems that can be found in real-world applications are listed below:

Shortest Path Problems:

(a) Navigation Services: Utilized routinely for figuring out the shortest course between two focuses on a map. On the map, there will be numerous places to arrive at movement between two destinations and this calculation will assist with tracking down the shortest conceivable ways.

(b) During Planning Trips: This calculation is utilized when we plan for trips utilizing various websites, when we attempt to book trips between two destinations, a comparative calculation is utilized to find the briefest way with the least delay time.

(c) Networking multiple PCs: This calculation can be utilized to transfer data from one PC to another with the shortest path. This can be very useful in big companies which need big data files on multiple PCs.

Maximum Flow Problems:

(a) Convention Planner: It can be utilized to know the maximum number of people to be invited.

(b) Scheduling of Airlines: Scheduling of airlines can be considered a maximum flow problem as in they have the data on the source and objective timing so they can utilize the model to maximize the number of airlines on one route.

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