

Module 07 – Maximal Flow

Exploratory Data Analysis

In this section, you should perform some data analysis on the data provided to you. Please format your findings in a visually pleasing way and please be sure to include these cuts:

- *Make a visual graph of your data like what we saw for the sample problem*
 - o <https://excalidraw.com>
 - o <https://mermaid.live>
 - o <https://dreampuf.github.io/GraphvizOnline>
 - o Powerpoint/Word

Model Formulation

Write the formulation of the model into here prior to implementing it in your Excel model. Be explicit with the definition of the decision variables, objective function, and constraints.

MAX: X_{70}

$$+X_{70}-X_{01}-X_{02}-X_{03}=0$$

$$+X_{01}-X_{14}-X_{16}=0$$

$$+X_{02}-X_{24}-X_{25}-X_{26}=0$$

$$+X_{03}-X_{34}-X_{36}=0$$

$$+X_{14}-X_{24}+X_{34}-X_{47}=0$$

$$+X_{25}-X_{54}-X_{57}=0$$

$$+X_{16}+X_{26}+X_{36}-X_{67}=0$$

$$+X_{47}+X_{57}+X_{67}-X_{70}=0$$

With the following bounds on the decision variables:

$$0 \leq X_{01} \leq 188$$

$$0 \leq X_{24} \leq 294$$

$$0 \leq X_{57} \leq 469$$

$$0 \leq X_{02} \leq 352$$

$$0 \leq X_{25} \leq 72$$

$$0 \leq X_{03} \leq 163$$

$$0 \leq X_{36} \leq 173$$

Model Optimized for Maximal Flow

Implement your formulation into Excel and be sure to make it neat. This section should include:

- *A screenshot of your optimized final model (formatted nicely, of course)*
- *A text explanation of what your model is recommending, especially any identified bottlenecks*
- *Update your graph from the EDA section to bold/color the links being used (and show how much is going through that link)*

Units of Flow	Links			Upper Bound
	From	To		
188	0 Butter Pecan Bluff	1 Cinnamon Swamp		188
352	0 Butter Pecan Bluff	2 Cocoa Bean Crater		352
163	0 Butter Pecan Bluff	3 Melty Mint Mountains		163
158	1 Cinnamon Swamp	4 Peppermint Peninsula		181
30	1 Cinnamon Swamp	6 Tartberry Thicket		73
115	2 Cocoa Bean Crater	4 Peppermint Peninsula		294
72	2 Cocoa Bean Crater	5 Tangerine Taffy Tropics		72
165	2 Cocoa Bean Crater	6 Tartberry Thicket		165
0	3 Melty Mint Mountains	4 Peppermint Peninsula		250
163	3 Melty Mint Mountains	6 Tartberry Thicket		173
273	4 Peppermint Peninsula	7 Turkish Delight Tundra		273
72	5 Tangerine Taffy Tropics	7 Turkish Delight Tundra		469
0	5 Tangerine Taffy Tropics	4 Peppermint Peninsula		205
358	6 Tartberry Thicket	7 Turkish Delight Tundra		459
703	7 Turkish Delight Tundra	0 Butter Pecan Bluff		9999

Nodes		Inflow	Outflow	Net Flow	Supply/Demand
0	Butter Pecan Bluff	703	703	0	0
1	Cinnamon Swamp	188	188	0	0
2	Cocoa Bean Crater	352	352	0	0
3	Melty Mint Mountains	163	163	0	0
4	Peppermint Peninsula	273	273	0	0
5	Tangerine Taffy Tropics	72	72	0	0
6	Tartberry Thicket	358	358	0	0
7	Turkish Delight Tundra	703	703	0	0

Maximum Flow	
	703

The Model recommends that the Maximum Flow of 703 units from the source node (Butter Pecan Bluff, Node 0) to the sink node (Turkish Delight Tundra, Node 7). This is achieved by distributing flow through the available network of paths, while respecting each arc's capacity constraints.

- The model is efficiently used as the shortest and highest-capacity routes from the source to the sink.
- Flow is distributed across multiple paths to maximizes throughout, using intermediate nodes like Cocoa Bean Crater (Node 2), Tart berry Thicket (Node 6), and Peppermint Peninsula (Node 4).

The Bottlenecks:

- Full capacity ($X_{01}, X_{02}, X_{03}, X_{25}, X_{26}, X_{36}, X_{57}, X_{67}, X_{70}$)

Model with Stipulation

Please copy the tab of your original model before continuing with the next part to avoid messing up your original solution.

Let's demonstrate the "Flow Aggregation" special consideration that was discussed in the textbook and the Follow Along – Model Formulation video. Please follow these steps:

- *Identify an edge that is not used with your current solution*
 - *If by chance all your edges are in use, then apply the next step to an under-utilized edge*
- *Add a lower bound (LB) constraint to that edge (i.e. there must be a non-zero flow to the edge)*
 - *The LB should be 10% of the capacity of that edge (i.e. if the unused edge supports 500 unit flow, then we should had a LB of 50 units through that edge)*
- *Discuss the changes to the optimal solution with this change and how it impacts the model formulation*

Units of Flow	Links		Upper Bound
	From	To	
188	0 Butter Pecan Bluff	1 Cinnamon Swamp	188
352	0 Butter Pecan Bluff	2 Cocoa Bean Crater	352
163	0 Butter Pecan Bluff	3 Melty Mint Mountains	163
181	1 Cinnamon Swamp	4 Peppermint Peninsula	181
73	1 Cinnamon Swamp	6 Tartberry Thicket	73
294	2 Cocoa Bean Crater	4 Peppermint Peninsula	294
72	2 Cocoa Bean Crater	5 Tangerine Taffy Tropics	72
165	2 Cocoa Bean Crater	6 Tartberry Thicket	165
250	3 Melty Mint Mountains	4 Peppermint Peninsula	250
173	3 Melty Mint Mountains	6 Tartberry Thicket	173
273	4 Peppermint Peninsula	7 Turkish Delight Tundra	273
469	5 Tangerine Taffy Tropics	7 Turkish Delight Tundra	469
205	5 Tangerine Taffy Tropics	4 Peppermint Peninsula	205
358	6 Tartberry Thicket	7 Turkish Delight Tundra	358
9999	7 Turkish Delight Tundra	0 Butter Pecan Bluff	9999

Nodes	Inflow	Outflow	Net Flow	Supply/Demand
0 Butter Pecan Bluff	703	703	0	0
1 Cinnamon Swamp	188	188	0	0
2 Cocoa Bean Crater	352	352	0	0
3 Melty Mint Mountains	163	163	0	0
4 Peppermint Peninsula	273	273	0	0
5 Tangerine Taffy Tropics	72	72	0	0
6 Tartberry Thicket	358	358	0	0
7 Turkish Delight Tundra	703	703	0	0

Maximum Flow
703

