Valeria Santoni

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*
  - https://excalidraw.com
  - https://mermaid.live
  - https://dreampuf.github.io/GraphvizOnline
  - 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}
$+X_{70}-X_{01}-X_{02}-X_{03}=0$
$+X_{01}+X_{31}-X_{12}-X_{14}=0$
$+X_{02}+X_{12}-X_{24}=0$
$+X_{03}-X_{31}-X_{35}=0$
$+X_{14}+X_{24}-X_{45}-X_{47}=0$
$+X_{35}+X_{45}-X_{56}-X_{57}=0$
$+X_{56}-X_{67}=0$
$+X_{47}+X_{57}+X_{67}-X_{70}=0$

With the following bounds on the decision variables:
$0\leq=X_{01}\leq=395$ $0\leq=X_{12}\leq=126$ $0\leq=X_{31}\leq=241$ $0\leq=X_{45}\leq=264$ $0\leq=X_{67}\leq=192$

$0\leq=X_{02}\leq=340$ $0\leq=X_{14}\leq=216$ $0\leq=X_{35}\leq=125$ $0\leq=X_{57}\leq=140$ $0\leq=X_{70}\leq$ =inf

$0\leq=X_{03}\leq=115$ $0\leq=X_{24}\leq=201$ $0\leq=X_{47}\leq=273$ $0\leq=X_{56}\leq=90$

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*

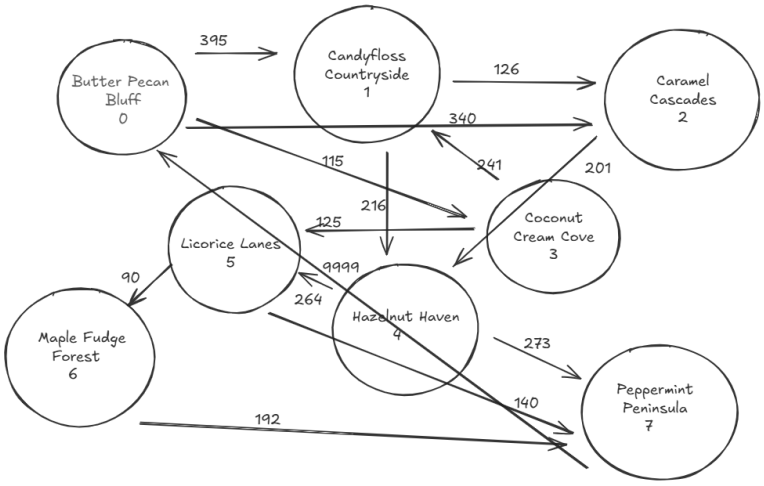
- *Update your graph from the EDA section to bold/color the links being used (and show how much is going through that link)*

Maximal Flow -> 503

Units of Flow	Links From		To		Upper Bound
216	0	Butter Pecan Bluff	1	Candyfloss Countryside	**395**
172	0	Butter Pecan Bluff	2	Caramel Cascades	**340**
115	0	Butter Pecan Bluff	3	Coconut Cream Cove	**115**
0	1	Candyfloss Countryside	2	Caramel Cascades	**126**
216	1	Candyfloss Countryside	4	Hazelnut Haven	**216**
172	2	Caramel Cascades	4	Hazelnut Haven	**201**
0	3	Coconut Cream Cove	1	Candyfloss Countryside	**241**
115	3	Coconut Cream Cove	5	Licorice Lanes	**125**
273	4	Hazelnut Haven	7	Peppermint Peninsula	**273**
115	4	Hazelnut Haven	5	Licorice Lanes	**264**
140	5	Licorice Lanes	7	Peppermint Peninsula	**140**
90	5	Licorice Lanes	6	Maple Fudge Forest	**90**
90	6	Maple Fudge Forest	7	Peppermint Peninsula	**192**
503	7	Peppermint Peninsula	0	Butter Pecan Bluff	**9999**

Nodes		Inflow	Outflow	Net Flow	Supply / Demand
0	Butter Pecan Bluff	503	503	0	**0**
1	Candyfloss Countryside	216	216	0	**0**
2	Caramel Cascades	172	172	0	**0**
3	Coconut Cream Cove	115	115	0	**0**
4	Hazelnut Haven	388	388	0	**0**
5	Licorice Lanes	230	230	0	**0**
6	Maple Fudge Forest	90	90	0	**0**
7	Peppermint Peninsula	503	503	0	**0**

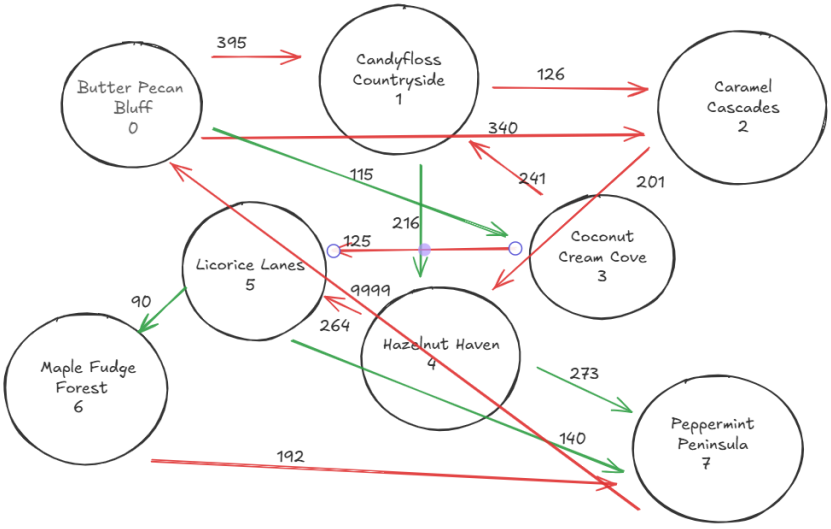
-



- *The maximum flow from source node, Butter Pecan Bluff to sink node, Peppermint Peninsula, is 503 units. This means that no more than 503 units can be transported across the network without exceeding any constraints on the links. Several links in the network operate at their full capacity, meaning they are bottlenecks limiting further flow. Some links have unused capacity, such as: Candyfloss Countryside → Caramel Cascades (0/126) and Coconut Cream Cove → Candyfloss Countryside (0/241). Reallocating unused capacity might help reduce pressure on overloaded links. There are a lot of edges that have flow equal to their upper bound like X_{03}, X_{14}, X_{47}, and more. Expanding bottleneck links could increase maximal flow beyond 503 units if needed.*

Model Stipulation Alternative: Identify the Bottlenecks
How many units reach each node?
Identify underutilized(RED) and those at capacity(Green) with different colors

What would help increase the optimal solution? We could have delivered more but it wasn't possible. In order to increase the optimal solution, we would like to increase those that are at capacity. X_{31} is not being used but could have been utilized.



			Maximal Flow ->		503							
Units of Flow	Links				Upper Bound		Nodes		Inflow	Outflow	Net Flow	Supply / Demand
	From		To									
216	**0**	Butter Pecan Bluff	**1**	Candyfloss Countryside	**395**		**0**	Butter Pecan Bluff	503	503	0	**0**
172	**0**	Butter Pecan Bluff	**2**	Caramel Cascades	**340**		**1**	Candyfloss Countryside	216	216	0	**0**
115	**0**	Butter Pecan Bluff	**3**	Coconut Cream Cove	**115**		**2**	Caramel Cascades	172	172	0	**0**
0	**1**	Candyfloss Countryside	**2**	Caramel Cascades	**126**		**3**	Coconut Cream Cove	115	115	0	**0**
216	**1**	Candyfloss Countryside	**4**	Hazelnut Haven	**216**		**4**	Hazelnut Haven	388	388	0	**0**
172	**2**	Caramel Cascades	**4**	Hazelnut Haven	**201**		**5**	Licorice Lanes	230	230	0	**0**
0	**3**	Coconut Cream Cove	**1**	Candyfloss Countryside	**241**		**6**	Maple Fudge Forest	90	90	0	**0**
115	**3**	Coconut Cream Cove	**5**	Licorice Lanes	**125**		**7**	Peppermint Peninsula	503	503	0	**0**
273	**4**	Hazelnut Haven	**7**	Peppermint Peninsula	**273**							
115	**4**	Hazelnut Haven	**5**	Licorice Lanes	**264**							
140	**5**	Licorice Lanes	**7**	Peppermint Peninsula	**140**							
90	**5**	Licorice Lanes	**6**	Maple Fudge Forest	**90**							
90	**6**	Maple Fudge Forest	**7**	Peppermint Peninsula	**192**							
503	**7**	Peppermint Peninsula	**0**	Butter Pecan Bluff	**9999**							

Model with Stipulation (DON'T DO THIS)

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*