# 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:$X_{70}$

Subject to:

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

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

$X_{02} - X_{24} = 0$

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

$X_{14} + X_{24} + X_{34} - X_{45} = 0$

$X_{45} - X_{56} - X_{57} = 0$

$X_{56} - X_{67} = 0$

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

Bounds:

$0 \le X_{01} \le 369$ $0 \le X_{14} \le 193$ $0 \le X_{45} \le 151$

$0 \le X_{02} \le 389$ $0 \le X_{24} \le 81$ $0 \le X_{56} \le 99$

$0 \le X_{03} \le 138$ $0 \le X_{34} \le 111$ $0 \le X_{57} \le 222$

$0 \le X_{67} \le 365$ $0 \le X_{70} \le 9999$

**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)*

Between the source node, Butter Rum Reef to the sink node, Starburst Starlit Skies. The optimal model yields a maximum flow of 385 units. The network distributes flow over several channels, making sure that each link maintains its capacity and that each node has a balanced inlet and outflow. Nineteen units connect Node 0 to Node 1 to Node 5, 81 units

connect Node 0 to Node 2 to Node 4, and 111 units connect Node 0 to Node 3 to Node 6. These are the principal pathways. After that, these flows pass Nodes 4, 5, and 6 in the direction of Node 7. The system has been shown to have multiple bottlenecks. The connections between Nodes 6 and 7 (210 units), 3 and 6 (111 units), and 4 and 7 (81 units) are all completely saturated. These are the network's most important restrictions, preventing additional traffic. The flow graph should be changed to make it easier to understand.

**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*

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Max Flow-> | 385 | |
| Units of Flow | Links To | | From | | Upper Bound | |
| 193 | 0 | Butter Rum Reef | 1 | Choco Volcano | 369 | |
| 81 | 0 | Butter Rum Reef | 2 | Chocolate River Rapids | 389 | |
| 111 | 0 | Butter Rum Reef | 3 | Frosted Fluff Fields | 138 | |
| 193 | 1 | Choco Volcano | 5 | Molasses Marsh | 193 | |
| 81 | 2 | Chocolate River Rapi | 4 | Frozen Fudge Fjords | 81 | |
| 0 | 3 | Frosted Fluff Fields | 1 | Choco Volcano | 199 | |
| 0 | 3 | Frosted Fluff Fields | 2 | Chocolate River Rapids | 106 | |
| 111 | 3 | Frosted Fluff Fields | 6 | Sprinkle Street | 111 | |
| 81 | 4 | Frozen Fudge Fjords | 7 | Starburst Starlit Skies | 322 | |
| 0 | 4 | Frozen Fudge Fjords | 5 | Molasses Marsh | 151 | |
| 94 | 5 | Molasses Marsh | 7 | Starburst Starlit Skies | 222 | |
| 99 | 5 | Molasses Marsh | 6 | Sprinkle Street | 99 | |
| 210 | 6 | Sprinkle Street | 7 | Starburst Starlit Skies | 365 | |
| 385 | 7 | Starburst Starlit Skie | 0 | Butter Rum Reef | 9999 | |

| | Nodes | Inflow | Outflow | Net Flow | Supply / Demand |
|---|---|---|---|---|---|
| 0 | Butter Rum Reef | 385 | 385 | 0 | 0 |
| 1 | Choco Volcano | 193 | 193 | 0 | 0 |
| 2 | Chocolate River Rapids | 81 | 81 | 0 | 0 |
| 3 | Frosted Fluff Fields | 111 | 111 | 0 | 0 |
| 4 | Frozen Fudge Fjords | 81 | 81 | 0 | 0 |
| 5 | Molasses Marsh | 193 | 193 | 0 | 0 |
| 6 | Sprinkle Street | 210 | 210 | 0 | 0 |
| 7 | Starburst Starlit Skies | 385 | 385 | 0 | 0 |