# Flow Report

*Bureau of Investigative Matters on behalf of the glorious Soviet Motherland, Group C*

*November 10, 2018*

## Results

Our implementation successfully computes a flow of 163 on the input file, confirming the analysis of the Imperialist scum.

We have analysed the possibilities of descreasing the capacities near Minsk. Our analysis is summarised in the following table:

| Case | 4W–48 | 4W–49 | Effect on flow |
|------|-------|-------|----------------|
| 0 | 30 | 30 | no change |
| 1 | 10 | 10 | $-20$ |
| 2 | 10 | 20 | $-10$ |
| 3 | 20 | 10 | $-10$ |
| 4 | 20 | 20 | no change |
| 5 | 30 | 10 | no change |
| 6 | 10 | 30 | no change |
| 7 | 30 | 20 | no change |
| 8 | 20 | 30 | no change |

Bellow we analyze the findings:

| From | From id | To | To id | Flow | Capacity |
|------|---------|-----|-------|------|----------|
| 2 | 1 | 45 | 19 | 6 | 6 |
| 2 | 1 | 46 | 18 | 12 | 12 |
| 3W | 17 | 46 | 18 | 2 | 2 |
| 3E | 16 | 4E | 15 | 4 | 4 |
| 2S | 2 | 6 | 13 | 24 | 24 |
| 52 | 10 | 8 | 9 | 16 | 16 |
| 52 | 10 | 7 | 11 | 4 | 4 |
| 52 | 10 | 51 | 25 | 2 | 2 |
| R | 27 | b | 26 | 8 | 8 |
| 10 | 7 | 7 | 11 | 10 | 10 |
| 7 | 11 | 51 | 25 | 28 | 28 |
| 7 | 11 | 50 | 24 | 34 | 34 |
| 5 | 12 | 49 | 23 | 12 | 12 |
| 46 | 18 | 47 | 22 | 20 | 20 |
| 4W | 20 | 5 | 12 | 4 | 4 |
| 4W | 20 | 49 | 23 | 10 | 10 |
| 4W | 20 | 48 | 21 | 10 | 10 |
| b | 28 | H | 30 | 19 | 19 |
| b | 26 | 51 | 25 | 8 | 8 |
| 50 | 24 | b | 33 | 17 | 17 |
| 49 | 23 | b | 35 | 2 | 2 |
| b | 29 | H | 30 | 5 | 5 |
| H | 30 | 1 | 42 | 16 | 16 |
| 1 | 38 | 2 | 46 | 30 | 30 |
| b | 35 | 1 | 38 | 2 | 2 |
| b | 34 | 4 | 39 | 36 | 36 |
| 4 | 39 | 8 | 44 | 16 | 16 |
| 4 | 39 | 5 | 45 | 36 | 36 |
| b | 33 | 4 | 39 | 17 | 17 |
| 7 | 40 | 8 | 44 | 24 | 24 |
| b | 31 | S | 41 | 10 | 10 |
| 1 | 42 | B | 50 | 10 | 10 |
| M | 43 | 9 | 49 | 3 | 3 |
| 5 | 45 | 9 | 49 | 25 | 25 |
| 2 | 46 | 6 | 48 | 29 | 29 |

In case 1, the new bottleneck table becomes as above.

| From | From id | To | To id | Flow | Capacity |
|---|---|---|---|---|---|
| 2 | 1 | 45 | 19 | 6 | 6 |
| 2 | 1 | 46 | 18 | 12 | 12 |
| 3W | 17 | 46 | 18 | 2 | 2 |
| 3W | 17 | 4W | 20 | 34 | 34 |
| 3E | 16 | 4E | 15 | 4 | 4 |
| 2S | 2 | 6 | 13 | 24 | 24 |
| 52 | 10 | 8 | 9 | 16 | 16 |
| 52 | 10 | 7 | 11 | 4 | 4 |
| 52 | 10 | 51 | 25 | 2 | 2 |
| R | 27 | b | 26 | 8 | 8 |
| 10 | 7 | 7 | 11 | 10 | 10 |
| 7 | 11 | 51 | 25 | 28 | 28 |
| 7 | 11 | 50 | 24 | 34 | 34 |
| 5 | 12 | 49 | 23 | 12 | 12 |
| 46 | 18 | 47 | 22 | 20 | 20 |
| 4W | 20 | 5 | 12 | 4 | 4 |
| 4W | 20 | 49 | 23 | 20 | 20 |
| 4W | 20 | 48 | 21 | 10 | 10 |
| b | 28 | H | 30 | 19 | 19 |
| b | 26 | 51 | 25 | 8 | 8 |
| 50 | 24 | b | 33 | 17 | 17 |
| 49 | 23 | b | 35 | 2 | 2 |
| b | 29 | H | 30 | 5 | 5 |
| H | 30 | 1 | 42 | 16 | 16 |
| 1 | 38 | 2 | 46 | 30 | 30 |
| b | 35 | 1 | 38 | 2 | 2 |
| b | 34 | 4 | 39 | 36 | 36 |
| 4 | 39 | 8 | 44 | 16 | 16 |
| 4 | 39 | 5 | 45 | 36 | 36 |
| b | 33 | 4 | 39 | 17 | 17 |
| b | 32 | 7 | 40 | 29 | 29 |
| 7 | 40 | 8 | 44 | 24 | 24 |
| b | 31 | S | 41 | 10 | 10 |
| 1 | 42 | B | 50 | 10 | 10 |
| M | 43 | 9 | 49 | 3 | 3 |
| 5 | 45 | 9 | 49 | 25 | 25 |
| 2 | 46 | 6 | 48 | 29 | 29 |

In case 2, the new bottleneck becomes as above.

| From | From id | To | To id | Flow | Capacity |
|---|---|---|---|---|---|
| 2 | 1 | 45 | 19 | 6 | 6 |
| 2 | 1 | 46 | 18 | 12 | 12 |
| 3W | 17 | 46 | 18 | 2 | 2 |
| 3W | 17 | 4W | 20 | 34 | 34 |
| 3E | 16 | 4E | 15 | 4 | 4 |
| 2S | 2 | 6 | 13 | 24 | 24 |
| 52 | 10 | 8 | 9 | 16 | 16 |
| 52 | 10 | 7 | 11 | 4 | 4 |
| 52 | 10 | 51 | 25 | 2 | 2 |
| R | 27 | b | 26 | 8 | 8 |
| 10 | 7 | 7 | 11 | 10 | 10 |
| 7 | 11 | 51 | 25 | 28 | 28 |
| 7 | 11 | 50 | 24 | 34 | 34 |
| 5 | 12 | 49 | 23 | 12 | 12 |
| 46 | 18 | 47 | 22 | 20 | 20 |
| 4W | 20 | 5 | 12 | 4 | 4 |
| 4W | 20 | 49 | 23 | 10 | 10 |
| 4W | 20 | 48 | 21 | 20 | 20 |
| b | 28 | H | 30 | 19 | 19 |
| b | 26 | 51 | 25 | 8 | 8 |
| 50 | 24 | b | 33 | 17 | 17 |
| 49 | 23 | b | 35 | 2 | 2 |
| b | 29 | H | 30 | 5 | 5 |
| H | 30 | 1 | 42 | 16 | 16 |
| 1 | 38 | 2 | 46 | 30 | 30 |
| b | 35 | 1 | 38 | 2 | 2 |
| b | 34 | 4 | 39 | 36 | 36 |
| 4 | 39 | 8 | 44 | 16 | 16 |
| 4 | 39 | 5 | 45 | 36 | 36 |
| b | 33 | 4 | 39 | 17 | 17 |
| b | 32 | 7 | 40 | 29 | 29 |
| 7 | 40 | 8 | 44 | 24 | 24 |
| b | 31 | S | 41 | 10 | 10 |
| 1 | 42 | B | 50 | 10 | 10 |
| M | 43 | 9 | 49 | 3 | 3 |
| 5 | 45 | 9 | 49 | 25 | 25 |
| 2 | 46 | 6 | 48 | 29 | 29 |

In case 3, the new bottleneck becomes as above.

Our thorough investigation has uncovered that decreasing the Minsk capacity by up to 20 in total is acceptable and will not affect our Motherland's Glory.

Additionally, Independent sources suggest that the Party Secretary of Minsk has recently acquired a rare taste in gold. Capitalist gold. And from our findings it is clear that the Minsk infrastructure is struggling with a "financial deficit". Insinuating counterrevolutionary intent would be absurd of such an outstanding member of the Party. However, we recommend immediate and permanent disciplinary action be taken as a precaution.

## Implementation details

We use an implemenation of Ford–Fulkerson's flow method in order to calculate the maximum flow, as described in Jon Kleinberg and Eva Tardos, *Algorithm Design*, chap. 7.

Since the railway is considered undirected, we have decided to represent it with an undirected graph that we treat as a directed graph in which each undirected edge is represented by two directed edges facing opposite directions and holding equal capacities. We create the residual network by decreasing the flow of a reversed edge whenever a flow of an edge is increased. As for the actual traversal of the graph, a simple Breadth First traversal was used.

The running time is $O((m+n)C)$ for graphs with $m$ edges, $n$ nodes, and the largest capacity in the graph $C$. Represented as $O(mC)$ since $m > n/2$.

Our datatype for edge is this:

```
class Edge:
    origin: int
    destination: int
    capacity: int
    flow: int
    is_reversed: bool
```