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Decision Support System for Railway Companies

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1 Introduction

To cope with the surge of people travelling, the Great Western Railway (GWR) plans to develop a system to explore the maximum flows between two railway stations and the flow conditions on each segment between the two stations to help with relieving the traffic pressure.

We designed a decision support system for GWR free of charge that enables this functionality using Excel. We hope that GWR will be happy to further collaborate with us on this project, and we will be able to provide more comprehensive consulting services and a more advanced system. It is important to note that this system is not specially designed for GWR, and we would be happy to work with other railway companies on relevant projects.

2 How to Use the System

When the workbook is opened, an "Add-ins" tab will be automatically displayed in the toolbar, which will also disappear automatically when the workbook is closed (Erdoğan, 2016; Charles, 2018). The system relies on the functions under the "Ford-Fulkerson Algorithm" menu. Here are the main steps to complete the analysis.

- You may want to reset the workbook using the "0. Optional – Reset the workbook" function if the workbook has data that has been previously entered. This function will clear all user-entered and user-generated data. If you accidentally click on this button, please do not worry as we have set up a reconfirm step.
- If the workbook does not contain a "Stations" worksheet, please use the "1.1 Optional - Set up Stations sheet" function to create it. If the workbook already contains a sheet named "Stations", this function will not create a new sheet, so please do not create a sheet named "Stations" manually.
- Use the "1.2 Enter new station" function or the "Enter New Station" button to add a new station to the form in "Stations", only one station at a time. All you need to do is enter the name of the station. This function does not allow the entry of duplicate station names, so if you have stations with the same name, please use a different number in the name to distinguish them. Please do not enter the data manually unless you completely understand the correct format for input.
- If the workbook does not contain a "Rail Segments" worksheet, please use the "2.1 Optional - Set up Rail Segments sheet" function to create it. Also, please do not create the worksheet manually.

➢ Use the "2.2 Enter new link" function or the "Enter New Link" button to enter all necessary railway sections and their maximum daily flow, only one link at a time. You need to select the origin station and destination station from the list of stations and indicate the capacity (maximum daily flow). This function does not allow you to enter a link that already exists, but it tells you which Link ID corresponds to this link so that you can change its capacity manually. Please do not enter new links manually unless you fully understand the correct input format.

➢ The "3. Optional – Find max flow for all pairs" function will output the maximum daily flow for all origin-destination pairs in the "All flows" worksheet. This can be a very time-consuming process, depending on the data size.

➢ If there is no "User" sheet in the workbook, use the "4.1 Set up User sheet" function to create the sheet. Also, please do not create the worksheet manually.

➢ Use the "4.2 Enter specific origin and destination" function or the "Enter Problem Data" button to enter an origin-destination pair for which you want to explore in detail its maximum daily flow.

➢ The last and most important function is "4.3 Run Ford-Fulkerson", which outputs the maximum daily flow from the origin to the destination in the "Optimal flows" worksheet, as well as details of the capacity of each rail segment. Five trials were carried out, and the results are presented in Fig. 1 and Appendix 1 (Fig. 3, Fig. 4, Fig. 5, Fig. 6). Note that only 34 major railway stations were used in our trials. As can be seen, the result contains the origin and destination stations, the maximum daily flow between them and conditions of all the railway segments between them ("Capacity" indicates the maximum daily flow for each segment, "Flow" indicates the flow of each segment that needs to be used in order to reach the maximum daily flow, and "Residual Capacity" indicates the remaining flow for each segment).

Origin	Destination	Max Flow
Swansea (Node ID: 1)	Paignton (Node ID: 20)	12

LinkID	Start	End	Flow	Residual Capacity	Capacity
9	1	2	12	8	20
10	2	3	12	11	23
12	3	5	12	13	25
22	5	17	12	16	28
25	17	18	12	14	26
26	18	19	12	14	26
27	19	20	12	0	12

Fig. 1. The output of daily flow from Swansea to Paignton

3 Advantages and Limitations

3.1 Advantages

Our decision support system has several strengths.

- The system is designed to be simple and can be quickly picked up by non-technical staff.
- The analysis can be done using an excel spreadsheet, no additional software is required.
- The result in the "All flows" worksheet allows the user to overview the maximum daily flow for each origin-destination pair and analyse the result directly in the worksheet to filter the origin-destination pairs that the user wants to explore in more depth.

3.2 Limitations

Our decision support system also has several limitations, which are also considered as the system's assumptions.

- Due to some parameters set in the VBA program, the user is able to enter a maximum of 9999 stations and 99999 links. We believe this parameter setting is suitable for all use cases. Of course, the user can break this restriction by modifying the VBA code, but we do not recommend the user to do so because the program will run much slower for large data sizes.
- It is not a real-time system, so it is only suitable for the situation when we anticipate the existence of a peak period in the future.
- The maximum flow of each railway segment should be obtained in advance. The data must include all stations and links between the origin and destination the user analyses.
- The decision system does not consider the capacity of competitors (i.e. other railway companies and other transportation companies), so the decision based on the result of this system may put the railway company at a disadvantage.
- The data in the "Rail Segments" worksheet must be numbered consecutively, otherwise, errors may occur. This is also one of the reasons why we do not recommend manual data entry.

4 Features of the System

4.1 Structure of the Worksheets

Our sample workbook contains all the necessary worksheets. If users have a missing worksheet when using it, they should follow the steps above to create the appropriate worksheet.

The data flow between worksheets is shown in Fig. 2. The user needs to enter necessary railway information in the "Stations" and "Rail Segments" worksheets. The "All flows"

worksheet will give an overview based on all the information entered by the user in the previous two worksheets, which can be ignored if the user is not interested in the overview. The “User” and “Optimal flows” worksheets will be the two most frequently used sheets.

The theme colours of the worksheet are black and grey, black for the header and grey for the data. In the yellow cells of the “User” worksheet, the user needs to enter two key variables (i.e. origin and destination stations) to achieve the system’s core functionality.

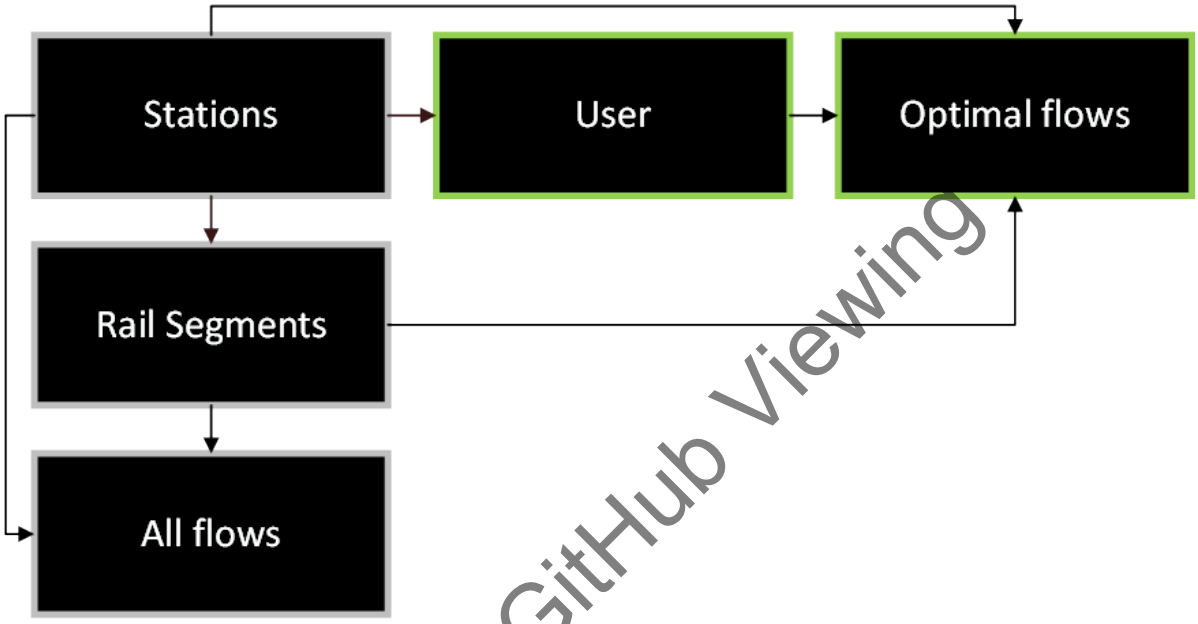

Fig. 2. The data flow in the system

4.2 Points of Attention

Each time the workbook is opened, one of the names[1] defined in the file is automatically refreshed, so the workbook will remind the user to save the document even if the user closes it without doing anything, which may be confusing and a bit annoying. In this case, the user can choose to save or not save the file.

Avoid creating worksheets or renaming them manually when using the system. Also, try to only use the functions in the “Add-ins” or buttons to enter data.

The system considers many of the bugs that may arise during use but does not guarantee to cover all situations that can cause the system to crash. We would love to hear feedback from

[1] In case readers are interested, check the name in the Name Manager. It is called “Stations_List”, which is used as the source of several dropdown boxes.

our users and actively improve the system.

5 Practical Applications

We focus on the applications of this decision support system for peak traffic periods. We assume that the number of tickets sold by the railway company is equal to the maximum capacity of each railway segment.

5.1 Train Scheduling and Route Planning

Railway companies can use the result in the "All flows" worksheet to identify the origin-destination pairs with low daily capacity. For these pairs, analyse the likelihood of their future congestion based on experience and the public planning for important future events. For these pairs with a high likelihood of future congestion, use the "User" and "Optimal flows" worksheets to explore the railway segments responsible for the low daily flows for these origin-destination pairs (i.e. railway segments with zero "Residual Capacity"). More trains or routes need to be scheduled for these railway segments.

For origin-destination pairs that are largely certain to encounter congestion in the future (e.g. a certain big event), train companies are supposed to explore their maximum daily flows and schedule more trains or routes for rail segments with low "Residual capacity", regardless of the result in the "All flows" worksheet.

However, as the system does not currently take into account the capacity of the competitors, there may be railway segments where our railway company's capacity is small but our competitors' capacity is large, in which case our train company may schedule redundant trains and routes, resulting in losses.

5.2 Ticket Price Regulation

During peak periods, tickets for routes between popular origins and destinations are a scarce resource, and parts of these popular routes may be shared by other routes, leading to further scarcity of tickets. Where this is the case, the railway company can increase the fares on each railway segment of the popular routes so that passengers with alternative routes do not take up tickets on these scarce options. The higher the fare can be for segments with less "Residual Capacity".

To maximise the strength of this decision support system, the user can replace the “Capacity” column in the “Rail Segments” sheet with the real-time remaining tickets of each segment to see the real-time “Residual Capacity” in the “Optimal flows” sheet. In this way, the railway company only needs to increase fares for segments with zero “Residual Capacity”.

Excel spreadsheets may struggle to achieve such real-time results. Worse still, as the system does not currently take into account the capacity of the competitors, there may be railway segments where our railway company’s capacity is small but our competitors’ capacity is large, in which case we will lose much more passengers if we still raise the fares of that segments.

5.3 Improvements

If the railway company is willing to cooperate further, our consulting team and programming team will create an even better decision support system that removes most of the existing limitations with state-of-the-art technology.

6 Conclusion

Although the current decision support system we have built for GWR has some limitations, it almost meets GWR’s needs and is easy to use. The system can help train companies make decisions about train scheduling, route planning and ticket price regulation, which will eventually mitigate congestion caused by the surge of travellers. If there are any bugs in the system or the user would like to implement more features, please call HoptimaL Consulting, and we will continue to improve the system. If any train companies would like to further cooperate with us on this project, please feel free to call us.

Appendix 1

Origin	Destination	Max Flow
Worcester Foregate Street (Node ID: 8)	Gatwick Airport (Node ID: 34)	20

LinkID	Start	End	Flow	Residual Capacity	Capacity
1	8	9	8	0	8
2	8	11	12	0	12
3	9	12	8	2	10
4	11	12	12	10	22
8	12	14	20	2	22
20	14	15	20	25	45
30	15	33	20	12	32
32	33	34	20	10	30

Fig. 3. The output of daily flow from Worcester Foregate Street to Gatwick Airport

Origin	Destination	Max Flow
Oxford (Node ID: 12)	Swindon (Node ID: 13)	55

LinkID	Start	End	Flow	Residual Capacity	Capacity
2	8	11	8	4	12
6	10	4	9	3	12
7	11	4	24	0	24
8	12	14	22	0	22
17	4	13	33	1	34
45	9	8	8	0	8
47	12	9	8	3	11
48	12	11	25	0	25
49	11	10	9	9	18
63	14	13	22	30	52

Fig. 4. The output of daily flow from Oxford to Swindon

Origin	Destination	Max Flow
Chippenham (Node ID: 7)	Swindon (Node ID: 13)	77

LinkID	Start	End	Flow	Residual Capacity	Capacity
4	11	12	17	5	22
8	12	14	17	5	22
11	3	4	11	5	16
13	5	4	24	0	24
17	4	13	34	0	34
18	7	13	26	0	26
24	7	23	16	0	16
51	4	11	17	11	28
56	5	3	11	17	28
58	7	4	16	0	16
59	6	5	21	0	21
60	7	6	19	0	19
63	14	13	17	35	52
66	17	5	14	18	32
67	23	6	2	10	12
77	23	17	14	10	24

Fig. 5. The output of daily flow from Chippenham to Swindon

Origin	Destination	Max Flow
Swindon (Node ID: 13)	Bristol Parkway (Node ID: 4)	114

LinkID	Start	End	Flow	Residual Capacity	Capacity
2	8	11	1	11	12
6	10	4	2	10	12
7	11	4	24	0	24
11	3	4	7	9	16
13	5	4	24	0	24
19	13	14	42	0	42
20	14	15	16	29	45
45	9	8	1	7	8
47	12	9	1	10	11
48	12	11	25	0	25
49	11	10	2	16	18
52	14	12	26	0	26
56	5	3	7	21	28
58	7	4	16	0	16
59	6	5	21	0	21
60	7	6	15	4	19
61	13	4	41	0	41
62	13	7	31	0	31
66	17	5	10	22	32
67	23	6	6	6	12
77	23	17	10	14	24
78	24	23	16	2	18
79	15	24	16	10	26

Fig. 6. The output of daily flow from Swindon to Bristol Parkway

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