

TRAFFIC CONGESTION PROBLEM OF ROAD NETWORKS IN KOTA KINABALU

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Abstract: Traffic congestion is an urban mobility problem that happens when the traffic volume exceeds the capacity of the road. In this century, human population is in surge, people tend to own private vehicles which cause traffic congestion. Besides, the poor management and road facilities worsen the traffic flow. In this study, maximum flow, bottleneck and shortest path are identified. Network from Indah Permai (IP) to Kota Kinabalu International Airport (KKIA) is the scope of this study. The capacity and distance of the routes within the scope are obtained from Dewan Bandaraya Kota Kinabalu (DBKK) and Google Map. With all the data, capacitated and weighted network graph formed. The objectives of this study are to find maximum flow, bottleneck and shortest path. Hence, Ford-Fulkerson algorithm, Max flow-Min cut theorem and Dijkstra's algorithm are applied. Next, the maximum flow and the shortest path problem were formulated into a linear programming model, and solved by using excel solver in Microsoft Excel. With the results, traffic congestion problem minimized and traffic flow became smooth.

Keywords: Traffic Congestion, Maximum flow, Bottleneck, Shortest Distance

I. INTRODUCTION

Traffic congestion is a common traffic problem in the entire world from year to year. There are several reasons that cause traffic congestions like bottlenecks, accidents, road conditions, road facilities, driver's driving behaviors, unrestricted owning vehicles and so forth. Traffic jam causes the traffic speeds slower, long trips time and long queues on the traffic. These phenomena are affecting the economic productivity and wasting of fuels and time. Apart from economic issues, traffic congestions also affected the quality of life and polluted the environment. There are two types of traffic congestion, namely, recurring congestion and non-recurring congestion. Recurring congestion is used to happen in the area of Central Business District (CBD) during peak hours of weekdays. Non-recurring congestion is an unexpected congestion due to accidents, sudden road closures, and maintenance which will slow the traffic flow. Moreover, non-recurring congestion is an unpredictable and troublesome traffic problem because it reduces the roadway capacity [1]. Hence, recurring congestion are considered and discussed in this study.

As reported by the Borneo Post, traffic congestion problem in Kota Kinabalu has becoming a major economic hindrance which stated by World Bank [2]. The contributing factor of traffic congestion was the abundance of vehicles on the road and inefficient public transportation in Kota Kinabalu which stated by Bernama [3]. The decrement of road capacity will decrease of maximum traffic flow and causing long queues and the dramatic drop of vehicle's speed in traffic. The scope of this study is the network from Indah Permai-IP (source node) to Kota Kinabalu International Airport-KKIA (sink node) where all the

routes between source and sink node are established. In Figure 1, the red spots are the selected major intersections which are assigned as the nodes of the network graph. This scope area is selected because this area is part of a central business district for Kota Kinabalu where the demand of traffic is higher than the other locations.

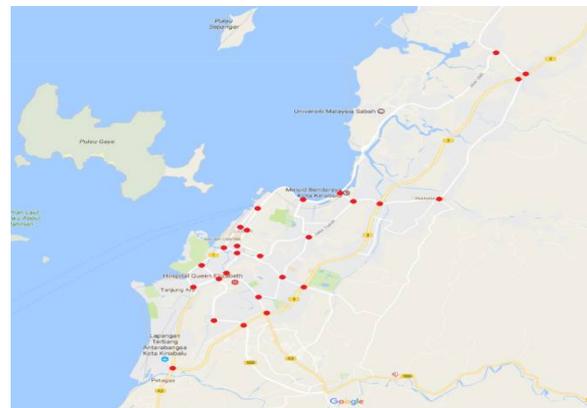


Figure 1: Scope of study (Within Kota Kinabalu Area)

Hence, the objectives of this study are to find the maximum flow of the desired routes as well as their bottlenecks, and determine the shortest path to reach the destination. Ford-Fulkerson algorithm computes the maximum flow while the max-flow and min-cut theorem identify the bottlenecks, and Dijkstra's algorithm is used to find the alternative shortest path.

II. LITERATURE REVIEW

An optimization of traffic flow within an urban traffic light intersection with Genetic algorithm in Kota Kinabalu, Sabah was studied [4]. The increase of on-road vehicles worsened congestion problems in Kota Kinabalu. Traffic light systems were built to control

and ensure the smoothness of traffic flows at the intersections. However, traffic light system cannot afford the increases of traffic flow and caused the long queue and congestion at intersection. The suggested solution was rebuilt of new traffic infrastructure like new roads and lanes but it became more difficult due to the limited land available. Hence, the better solution was to study and design a traffic light controller to optimize the traffic flow. The data like queue length, green time, cycle time and amber time was observed and studied through simulations. Genetic algorithm was selected to find the optimized solution of traffic flow. Throughout the simulation results, it showed that the Genetic algorithm gives fast and good respond to the change of queue length at the intersection.

The maximum flow problem and solution algorithm, Ford-Fulkerson algorithm in Ethiopian Airlines was investigated [5]. The maximum flow problem was solved by Ford-Fulkerson algorithm, the obtained maximum flow value was the same but number of augmenting paths, and flow of augmenting path might be different. It meant that the maximum flow value of the maximum problem was unique but it could have different augmenting path and different number of augmenting path.

The maximum flow in road networks with speed dependent capacities was applied to Bangkok traffic [6]. A traffic maximum flow problem had arcs represented as capacity of road (maximum vehicles per hour) that were functions of the traffic speed (kilometer per hour) and traffic density (vehicles per kilometer), empirical data on safe vehicle separations for a given speed were used to estimate road capacities for a given speed. A modified version of the Ford-Fulkerson algorithm was developed to solve maximum flow problems with speed-dependent capacities, with multiple source and target nodes. It was found that the maximum safe traffic flow occurs at the speed of 30 km/hr.

A method of path selection in the graph was presented [7]. In this paper, Dijkstra's algorithm was used to find additional paths among nodes in the maritime sector. Since it involved single criterion, therefore the shortest path was not always the best alternative path. Hence, other parameters were calculated such as the average time, number of indirect vertices, and the safety factor. Multi-criteria decision making used in this study for selecting one desirable path from several paths. Dempster-Shafer theory was a method that could be applied to combine data and evidences.

The simplest and smallest network on Ford-Fulkerson Maximum Flow procedure might fail to terminate [8]. Ford-Fulkerson is a labeling method that can always terminate networks graph that have rational capacity of the edges. However, it might fail to terminate in the sense that it has an infinite sequence of flow augmentations. The results suggested that network with real-valued capacities contain the subgraph

homeomorphic and irrational capacities. Therefore, Ford-Fulkerson algorithm might fail to terminate it.

Moreover, basic theory of highway traffic capacity and followed by the method of maximum flow algorithm to calculate the highway capacity was studied [9]. In traffic route map analysis, road capacity refers to the maximum number of vehicles at particular paths or edges. Traffic capacity of multi point, multi destination network is transformed to single starting point and single end point network problem. Network simplification process was performed to obtain the maximum flow of the network. It concluded that the results are the same as the results of the labeling method. Contribution of this paper is the transformation of the highway network capacity into a specific mathematical model and solved by simple maximum flow algorithm.

A research on method of traffic network bottleneck identification based on Max-flow Min-cut Theorem was performed [10]. It allows the weak section of the road to be identified and provide a solution for the traffic problem. The traffic networks must be formed into the map of graph theory before identification of bottleneck. It applied the Max-flow Min-cut Theorem to find out the bottleneck of the network. This theorem stated that the minimum cut is the smallest capacity of the road section. Therefore, it determines the maximum capacity of the whole network. The identified weak parts of the road allow traffic planar to know that which parts of the road need to be widened. The results show that identification of bottleneck based on Max-flow Min-cut Theorem can find out the bottleneck effectively.

An applied minimum-cut maximum-flow using cut set of a weighted graph on the traffic flow network [11]. A capacitated graph with a real number of capacity serves as a structural model in transportation. The traffic control strategy of minimal cut and maximum flow is to minimize number of edges in network and maximum capacity of vehicles which can move through these edges. The technique of minimal cut in traffic network allows shortening the waiting time of traffic participants and providing a smooth and uncongested traffic flow.

III. METHODOLOGY

3.1 Network Graph

Network is formed with edges that are connected with nodes. Capacitated network graph and weighted network graph are needed in this study to get the shortest path and maximal flow. First, a capacitated network graph formulates with all the edges. Each of the edges has a non-negative capacity, $c(u, v) \geq 0$ and flows $f(u, v)$ that cannot be more than capacity of the edge. The source node, s and sink node, t of a network are starting point, and ending point respectively. A capacitated network must fulfill the conditions below: First, the capacity constraint, $\forall (u, v) \in E f(u, v) \leq c(u, v)$ which flow of the

edges must not exceed its own capacity. Then, the next condition is skew symmetry, $\forall u, v \in V, f(u, v) = -f(v, u)$ which net flow from u to v and from v to u must be opposite to each other. Lastly, flow conservation constraints, $\forall u \in V: u \neq s \text{ and } u \neq t \Rightarrow \sum_{(s,u) \in E} f(s, u) = \sum_{(v,t) \in E} f(v, t)$ is the net flow to a node is zero except source node and sink node and the flow from the source node must be equal to the flow at the sink node. Weighted network graph is a network graph that formulates by the edges with the non-negative distances. It is almost the same as the capacitated network graph [12].

3.2 Ford-Fulkerson Algorithm

Maximal flow in a capacitated flow network is the total flow from a source node to a sink node. First, find an augmenting path from the source node to the sink node. After the formation of augmentation path, compute the bottleneck capacity. Lastly, augment each edge and the total flow until the capacity of sink node reaches maximum [13].

3.3 Dijkstra's Algorithm

First, assign to every node a tentative distance value. Then, label starting node with zero, and to infinity for all other nodes. Set starting node as temporary, and mark other nodes as unvisited nodes. For the temporary node, choose the unvisited arcs that are connected to the starting node with the least value. Mark the temporary node as visited as all the neighbors of the temporary node are considered. Temporarily label all the nodes that are connected to the permanent labelled nodes with the distances from starting node. Choose the temporary label of the least value. Repeat the steps until the destination node has a permanent label [14].

3.4 Maximum Flow and Minimum Cut Theorem

The minimum capacity of an (s,t)-cut is equal to the maximum value of a flow.

$$\max \{val(f) \mid f \text{ is a flow}\} \\ = \min \{cap(S, T) \mid (S, T) \text{ is an } \{s, t\} - \text{cut}\}$$

IV. DATA COLLECTION

Before maximum flow algorithm and shortest path algorithm being applied in this study, a network graph will be needed. To form a network graph, there were several data needed such as the name, direction, distance and capacity of the routes within selected scopes. The intersections appointed as the nodes of the network graph, the path that connected between the intersections were the edges with direction, distance and capacity of the road sections assigned according to the direction of the edges. With all the nodes, edges, direction and capacities, a directed network graph can be formed. Those data collected from Dewan Bandaraya Kota Kinabalu (DBKK), a city council in Kota Kinabalu and Google

Maps. They provided the reports of some of the projects that had been carried out recently. In the report, it had included the information on the routes like capacity. In paper [15] using direct empirical method for capacity estimation but in this paper was using traffic signal timing manual to get the capacity of the road [16].

Table 1: Capacity and Distance of the selected routes from IP-KKIA

Location Name	From	To	Capacity	Distance (Meter)
JalanSepanggar	S	V1	914	1600
Jalan UMS	S	V3	3103	11500
JalanTuaran 1	V1	V2	1394	350
JalanTuaran 2	V2	V4	1905	6700
JalanTuaran Bypass (North)	V2	V5	1151	8200
JalanTuaran Bypass (South)	V5	V2	1151	8200
JalanTuaran 3	V4	V5	2161	2000
Jalan Lintas 1	V5	V8	2877	5100
JalanTuaran 4(South)	V5	V6	2559	1000
JalanTuaran 4 (North)	V6	V5	2832	1000
JalanPasir (North)	V3	V6	1533	600
JalanPasir (South)	V6	V3	2500	600
JalanTunFuad Stephen 1	V3	V7	2000	1500
JalanTunFuad Stephen 2	V7	V10	1948	2400
JalanIstiadat&JalanKompleksSukan (North)	V7	V9	846	2100
JalanIstiadat&JalanKompleksSukan (South)	V9	V7	2120	2100
JalanTuaran 5 (South)	V9	V6	1902	2300
JalanTuaran 5 (North)	V6	V9	1648	2300
JalanDamai (North)	V9	V12	1687	2200
JalanDamai (South)	V12	V9	1289	2200
JalanTuaran 6 (North)	V9	V15	1807	2200
JalanTuaran 6 (South)	V15	V9	813	2200
Jalan KK Bypass 2 (North)	V10	V13	1897	1400
Jalan KK Bypass 2 (South)	V13	V10	1394	1400
JalanTunku Abdul Rahman 1 (North)	V13	V16	1482	600
JalanTunku Abdul Rahman 1 (South)	V16	V13	2575	600
JalanLaiamanDiki	V13	V14	809	290
JalanTunRazak	V10	V14	1995	1600
Jalan Coastal 1	V14	V17	2223	800
JalanKolam 1 (North)	V12	V15	2161	1400
JalanKolam 1 (South)	V15	V12	2161	1400
JalanKolam 2 (North)	V8	V12	1902	850
JalanKolam 2 (South)	V12	V8	2877	850
Jalan Lintas 2	V8	V11	2223	2000
Jalan Lintas 3	V11	V20	1561	900
JalanPenampang (North)	V11	V21	1388	2600
JalanPenampang (South)	V21	V11	1514	2600
JalanTuaran 7 (North)	V15	V18	3600	800
JalanTuaran 7 (South)	V18	V15	2726	800
JalanTunku Abdul Rahman 2 (North)	V16	V18	3757	150
JalanTunku Abdul Rahman 2 (South)	V18	V16	1482	150
JalanNenas (North)	V15	V16	1482	1100
JalanNenas (South)	V16	V15	1877	1100
JalanKemajuan	V18	V17	2262	450
JalanTunku Abdul Rahman 3 (North)	V18	V21	1078	1100
JalanTunku Abdul Rahman 3 (South)	V21	V18	3757	1100
JalanPintas 1 (North)	V20	V22	1251	1100
JalanPintas 1 (South)	V22	V20	2483	1100
JalanPintas 2 (North)	V22	V23	2200	2300
JalanPintas 2 (South)	V23	V22	1251	2300
JalanTunku Abdul Rahman 4 (North)	V21	V23	2200	350
JalanTunku Abdul Rahman 4 (South)	V23	V21	1948	350
Jalan Coastal 2	V17	V19	2559	1100
JalanSembulan (North)	V19	V23	3300	950
JalanSembulan (South)	V23	V19	1419	950
Jalan Coastal 3	V19	V24	4428	1400
Jalan Mat Salleh (North)	V23	V24	895	900

Jalan Mat Salleh (South)	V24	V23	2200	900
JalanKeapayan	V24	T	2426	4000
Jalan Lintas 4	V20	T	1591	3600

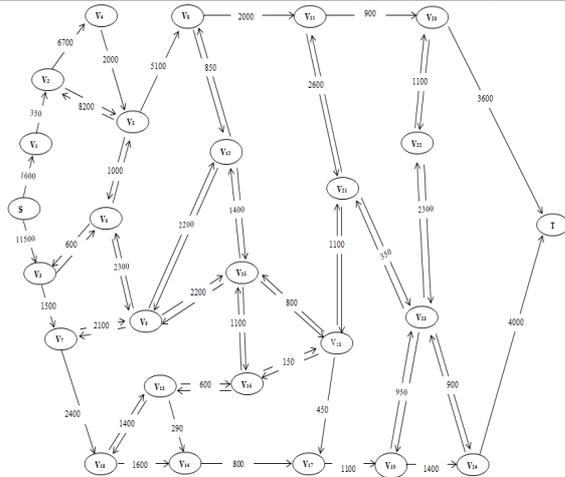


Figure 2: Weighted Directed Network Graph from IP to KKIA

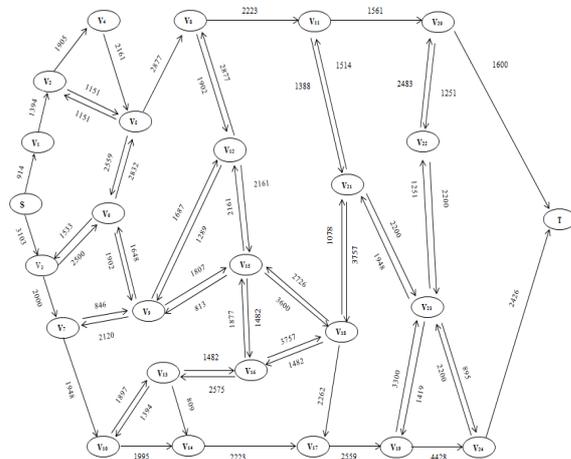


Figure 3: Capacitated Directed Network Graph from IP to KKIA

The data in Table 1 were used to form a weighted and capacitated directed network graph as shown in Figure 2 and Figure 3 respectively.

V. RESULTS AND DISCUSSIONS

5.1 Results of Maximum Flow Problem Using Algorithms

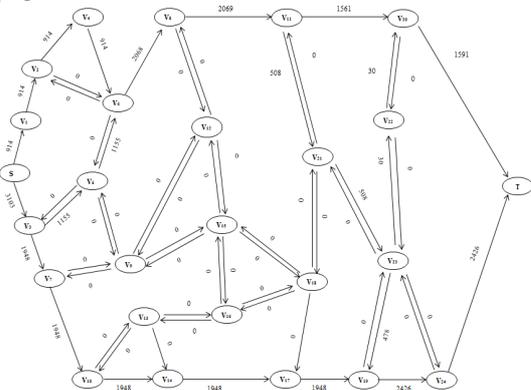


Figure 4: Optimal Solution of Maximum Flow Problem

Figure 4 showed the first augmenting path from $S \rightarrow V1 \rightarrow V2 \rightarrow V4 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V20 \rightarrow T$. Second augmenting path was $S \rightarrow V3 \rightarrow V6 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V20 \rightarrow T$. Third augmenting path was $S \rightarrow V3 \rightarrow V6 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V21 \rightarrow V23 \rightarrow V19 \rightarrow V24 \rightarrow T$. Fourth augmenting path was $S \rightarrow V3 \rightarrow V6 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V21 \rightarrow V23 \rightarrow V22 \rightarrow V20 \rightarrow T$. Fifth augmenting path was $S \rightarrow V3 \rightarrow V7 \rightarrow V10 \rightarrow V14 \rightarrow V17 \rightarrow V19 \rightarrow V24 \rightarrow T$. The maximum flow of first, second, third, fourth and fifth augmenting paths were 914, 647, 478, 30 and 1948 vehicles respectively. The total maximum flow of the whole network was 4017 of vehicles per hour.

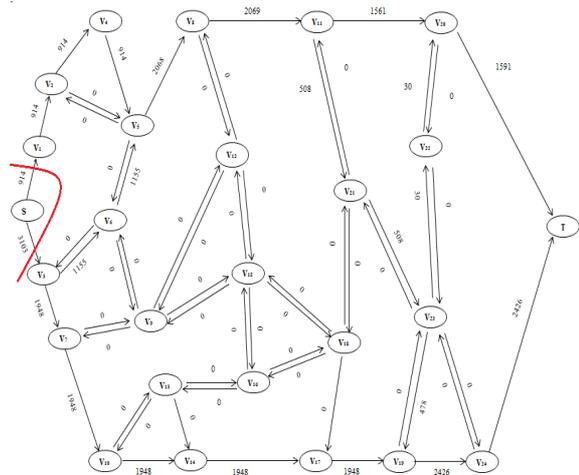


Figure 5: Bottlenecks of capacitated network graph

From Figure 5, the bottlenecks of the network were $S \rightarrow V1$ and $S \rightarrow V3$ because it had the smallest flow which was equal to the total maximum flow. $S \rightarrow V1$ was JalanSepanggar, and $S \rightarrow V3$ was Jalan UMS.

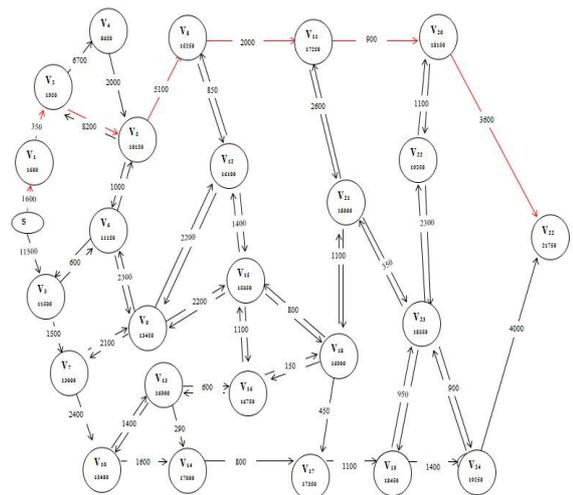


Figure 6: Results of Dijkstra's algorithm

From Figure 6, the shortest path in this weighted network graph was $S \rightarrow V1 \rightarrow V2 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V20 \rightarrow T$. It was about 21.75km from Indah Permai to Kota Kinabalu International Airport.

5.2 Results of Maximum Flow Problem Using Excel Solver

	A	B	C	D	E	F	G	H	I	J	K
3			From	To	Unit of Flow	Capacity		Node	Net Flow	Supply/Demand	
4		S	V1	914	≤	914		S	0	0	
5		S	V3	3103	≤	3103		V1	0	0	
6		V1	V2	914	≤	1394		V2	0	0	
7		V2	V4	914	≤	1905		V3	0	0	
8		V3	V6	1155	≤	1533		V4	0	0	
9		V6	V3	0	≤	2500		V5	0	0	
10		V2	V5	0	≤	1151		V6	0	0	
11		V5	V2	0	≤	1151		V7	0	0	
12		V3	V7	1948	≤	2000		V8	0	0	
13		V7	V9	0	≤	846		V9	0	0	
14		V9	V7	0	≤	2120		V10	0	0	
15		V7	V10	1948	≤	1948		V11	0	0	
16		V6	V9	0	≤	1902		V12	0	0	
17		V9	V6	0	≤	1648		V13	0	0	
18		V6	V5	1155	≤	2832		V14	0	0	
19		V5	V6	0	≤	2559		V15	0	0	
20		V4	V5	914	≤	2161		V16	0	0	
21		V5	V8	2069	≤	2877		V17	0	0	
22		V8	V12	0	≤	1902		V18	0	0	
23		V12	V8	0	≤	2877		V19	0	0	
24		V9	V12	0	≤	1687		V20	0	0	
25		V12	V9	0	≤	1289		V21	0	0	
26		V9	V15	0	≤	1807		V22	0	0	
27		V15	V9	0	≤	813		V23	0	0	
28		V15	V12	0	≤	2161		V24	0	0	
29		V12	V15	0	≤	2161		T	0	0	
30		V10	V13	0	≤	1897					
31		V13	V10	0	≤	1394					
32		V10	V14	1948	≤	1995					
33		V13	V14	0	≤	809					
34		V13	V16	0	≤	1482					
35		V16	V13	0	≤	2575					
36		V16	V18	0	≤	3757					
37		V18	V16	0	≤	1482					
38		V18	V21	0	≤	1078					
39		V21	V18	0	≤	3757					
40		V16	V15	0	≤	1877					
41		V15	V16	0	≤	1482					
42		V15	V18	0	≤	3600					
43		V18	V15	0	≤	2726					
44		V18	V17	0	≤	2262					
45		V11	V21	508	≤	1388					
46		V21	V11	0	≤	1514					
47		V20	V22	0	≤	1251					
48		V22	V20	30	≤	2483					
49		V8	V11	2069	≤	2223					
50		V11	V20	1561	≤	1561					
51		V21	V23	508	≤	2200					
52		V23	V21	0	≤	1948					
53		V23	V19	478	≤	1419					
54		V19	V23	0	≤	3300					
55		V14	V17	1948	≤	2223					
56		V17	V19	1948	≤	2559					
57		V19	V24	2426	≤	4428					
58		V24	T	2426	≤	2426					
59		V20	T	1591	≤	1600					
60		V23	V24	0	≤	895					
61		V24	V23	0	≤	2200					
62		V23	V22	30	≤	1251					
63		V22	V23	0	≤	2200					
64		T	S	4017	≤	99999999					
65											
66											
67											

Figure 8: Maximum flow problem Excel Output

In Figure 8, column G represented the capacity for each edge. The objective function was the cell G67 which contained the formula of ‘=E64’. Cell E64 was the maximum flow from node “s” to node “t”. The cell J4 to cell J29 represented the net flow which was the constraints cells. The units of flow, from cell E4 to cell E64, were the variable cells. Those variable cells that equal to zero were the unutilized paths. For the solver parameters, the cell G67 was set as the Objective. The maximum button was chosen in order to maximize the maximum flow problem. The changing variable cells were the cells from E4 to E64. Next, constraints were the Unit of Flow (cell E4 to E64) less than or equal to Capacity (cells G4 to G64) and Net Flow (cells J4 to J29) must equal to the Supply/Demand (cells K4 to K29). Simplex Linear Programming was selected as the solving method. The augmenting path of the maximum flow path by excel solver might not be the same as the augmenting path of the Ford-Fulkerson algorithm. However, the maximum flow value for Ford-Fulkerson algorithm and excel outputs were expected to be the same [17].

5.2 Results of Shortest Path Problem Using Excel Solver

	A	B	C	D	E	F	G	H	I	J
2			From	To	On Route	Route Distance (Meter)		Node	Net Flow	Supply/Demand
3		S	V1	1	=	1600		S	1	1
4		S	V3	0	=	11500		V1	0	0
5		V1	V2	1	=	350		V2	0	0
6		V2	V4	0	=	6700		V3	0	0
7		V2	V5	1	=	8200		V4	0	0
8		V5	V2	0	=	8200		V5	0	0
9		V4	V5	0	=	2000		V6	0	0
10		V5	V8	1	=	5100		V7	0	0
11		V5	V6	0	=	1000		V8	0	0
12		V6	V5	0	=	3000		V9	0	0
13		V3	V6	0	=	600		V10	0	0
14		V6	V3	0	=	600		V11	0	0
15		V3	V7	0	=	1500		V12	0	0
16		V7	V10	0	=	2400		V13	0	0
17		V7	V9	0	=	2100		V14	0	0
18		V9	V7	0	=	2100		V15	0	0
19		V9	V6	0	=	2300		V16	0	0
20		V6	V9	0	=	2300		V17	0	0
21		V9	V12	0	=	2200		V18	0	0
22		V12	V9	0	=	2200		V19	0	0
23		V9	V15	0	=	2200		V20	0	0
24		V10	V13	0	=	2200		V21	0	0
25		V10	V13	0	=	1400		V22	0	0
26		V13	V10	0	=	1400		V23	0	0
27		V13	V16	0	=	600		V24	0	0
28		V16	V13	0	=	600		T	-1	-1
29		V13	V14	0	=	290				
30		V10	V14	0	=	1600				
31		V14	V17	0	=	800				
32		V12	V15	0	=	1400				
33		V15	V12	0	=	1400				
34		V6	V12	0	=	850				
35		V12	V6	0	=	850				
36		V8	V11	1	=	2000				
37		V11	V20	1	=	900				
38		V11	V21	0	=	2600				
39		V21	V11	0	=	2600				
40		V15	V18	0	=	800				
41		V18	V15	0	=	800				
42		V16	V18	0	=	150				
43		V18	V16	0	=	150				
44		V15	V16	0	=	1100				
45		V18	V15	0	=	1100				
46		V17	V18	0	=	450				
47		V18	V17	0	=	450				
48		V18	V21	0	=	1100				
49		V21	V18	0	=	1100				
50		V20	V22	0	=	1100				
51		V22	V20	0	=	1100				
52		V22	V23	0	=	2300				
53		V23	V22	0	=	2300				
54		V21	V23	0	=	350				
55		V23	V21	0	=	350				
56		V17	V19	0	=	1100				
57		V19	V17	0	=	950				
58		V23	V19	0	=	950				
59		V19	V24	0	=	1400				
60		V23	V24	0	=	900				
61		V24	V23	0	=	900				
62		V24	T	0	=	4000				
63		V20	T	1	=	3600				
64										
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66										
67										

Figure 9: Shortest path problem solved by using simplex linear programming in Microsoft excel

In Figure 9, column F represented the distance of the edge. The objective function was the cell F66 which contained the formula of ‘=SUMPRODUCT (D4:D64,F4:F64)’. The cell from I4 to I29 represented the net flow were the constraints cells. The ‘On Route’ from cell D4 to cell D64 were the variable cells. The number ‘1’ showed in the column of ‘on route’ denoted for the route selected, and number ‘0’ denoted for route unselected. Hence, the selected routes for shortest path were from S→V1→V2→V5→V8→V11→V20→T. In the supply or demand column, that source node, “s” was set as number ‘1’ and the sink node, t was set as number ‘-1’ because both of the nodes were the starting and the ending nodes. For the excel solver parameters part, the cell F66 was set as the Objective. Since the goal was to find the shortest path, therefore the minimum button was chosen in order to minimize the shortest path problem. The changing variable cells were the cells from D4 to D64. Next, the constraints of the Net Flow (cells I4 to I29) must be equal to Supply/Demand (cell J4 to J29). Before clicking on the solve button, Simplex Linear Programming was selected as the solving method. The output of the shortest path by using the excel

solver would be the same as the output of the Dijkstra's algorithm [15].

CONCLUSION

In conclusion, the maximum flow of the capacitated network was 4017 vehicles per hour, while the identified bottleneck paths were Jalan Sepanggar and Jalan UMS. Besides, the number of augmenting path can be different but the maximum flow was still the same which is same result as [5]. Next, the shortest path in this weighted network graph was, $S \rightarrow V1 \rightarrow V2 \rightarrow V5 \rightarrow V8 \rightarrow V11 \rightarrow V20 \rightarrow$

Tviz. Jalan Sepanggar \rightarrow Jalan Tuaran \rightarrow Jalan Tuaran Bypass (North) \rightarrow Jalan Lintas \rightarrow Jalan Lintas \rightarrow Jalan Lintas \rightarrow Jalan Lintas, and it took about 21.75km from origin, I to destination, KKIA in Kota Kinabalu. Thus, with these outputs, traffic planar could think of the ways to improve the identified bottlenecks, and traffic drivers could avoid the bottleneck and chose the shortest path as their desire route.

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