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Road traffic analysis on the congestion problem using the Ford-Fulkerson algorithm

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A B S T R A C T

In this paper, the well-known Ford-Fulkerson algorithm in graph theory is used to determine the maximum flow in a road traffic network. Road traffic congestion is a major urban transport problem that occurs when the volume of traffic exceeds the capacity of existing road facilities. The manifestation of traffic congestion is due to the ownership of a high number of vehicles at the expense of road traffic infrastructure and the high growth of the urban population. Only one road connects the city center of Kinshasa, which concentrates the main activities of the inhabitants, to the international airport of Ndjili. Whether you are a pedestrian, a car driver or a public transport user, you cannot escape the traffic jams that refuse to leave Kinshasa. Even motorbike taxis cannot escape. Yet the grade separations built on Lumumba Boulevard in Debonhomme, at the Marché de la Liberté and at Pascal are all open to traffic. Built to facilitate the flow of traffic between the city center (Gombe) and N'djili International Airport, these elephantine structures serve little purpose. In this study, the identification of the maximum flow and bottleneck path along the Lumumba Boulevard between Debonhomme and Ndjili International Airport in the Tshangu district of Kinshasa was carried out. All possible routes from the different sources to the different wells were established. It emerged from this study that the optimal solutions would be the construction of secondary roads and improvement of the road facilities to minimize the problem of traffic congestion.

1. Introduction

Road traffic congestion is a major urban transport problem that occurs when the number of vehicles exceeds the capacity of existing road facilities (Zhu et al., 2021). Traffic congestion can be an urban mobility problem that affects the economic productivity and overall quality of life of many people (Teo et al., 2010; Afrin et al., 2020). The emergence of traffic jams is due to a significant increase in the number of vehicles and the unlimited growth of the urban population. In addition, the limited availability of infrastructure and the difficulty of reconstruction will lead to a slow improvement of the road infrastructure (Walraven et al., 2016; Wang et al., 2019).

Traffic congestion can be classified into two categories, namely recurrent congestion and non-recurrent congestion (Luan et al., 2021).

Recurrent congestion is known as peak hour traffic congestion that usually occurs in an area while non-recurrent congestion is caused by a number of unexpected events that slow down the traffic flow (Ma et al., 2020). Non-recurrent congestion is caused by accidents, road maintenance, road closures for events and natural disasters (Peres et al., 2018; Karaer et al., 2020). Non-recurrent congestion is a rather difficult problem to manage because it is unpredictable. Non-recurrent congestion can lead to temporary road closures, thus reducing road capacity (Tariq et al., 2020). The reduction in road capacity will result in a decrease in the maximum traffic flow, which will significantly slow down the speed of vehicles. The application of the Ford-Fulkerson algorithm, followed by the maximum flow and mini-cut theorem, will be used to identify bottlenecks in traffic congestion roads. These results will also allow the traffic planner to decide which road facilities should be improved.

Finally, the roads with low traffic congestion will be identified and then ranked as alternative routes for drivers (Zhang et al., 2020). The improvement of the bottleneck route should be put into practice, which allows traffic to move smoothly. Therefore, the main objective of this study is to apply mathematical concepts, namely the Ford-Fulkerson algorithm and the max-flow and min-cut theorem, to determine the maximum flow and identify the bottleneck path of traffic congestion problems (Ata et al., 2021).

2. Statement of the problem and scope of the study

Traffic congestion problems persist from day to day in the Tshangu District of Kinshasa. There are several reasons that have aggravated the traffic congestion problems, namely, the increase in urban population, the slow improvement of traffic facilities and the behavior of drivers on the road. However, in this study, the main criterion to be discussed is the performance of roadside facilities. Therefore, the maximum flow and bottleneck lanes were the part that needed to be identified in order to minimize traffic congestion problems. Different paths or roads will have a different maximum flow. The higher the maximum throughput, the lower the degree of congestion. On the other hand, bottlenecks limit the maximum throughput of a road. The maximum flow and minimum cut theorems allow to maximize the flow in a network and to take the maximum capacity of the road for traffic optimization purposes.

The scope of this study is a network that accommodates Lumumba Boulevard between Debonhomme and Ndjili International Airport in the Tshangu district of Kinshasa, of which Ndjili International Airport is the source and Debonhomme is the sink. All possible routes from the source to the well have been established. The Mikondo, Indu, Kulumba roads were selected as they are part of Tshangu. Traffic demand is high there and the risk of traffic jams is higher than elsewhere. Once the capacity network is formed, the maximum flow is calculated using the Ford-Fulkerson algorithm. Then, the maximum flow and minimum cut theorem is used to determine the minimum cut value and the bottlenecks of the selected network.

3. Methodology

Phase 1: Data collection

There are two different methods to perform traffic volume counts which are manual counts and automatic counts (Abdullah et al., 2017). The most common method of collecting traffic volume data would be the manual traffic volume counting method, which involves a group of people recording the number of vehicles passing over a predetermined location, using tally marks in inventories (Abdullah et al., 2017). There are also several methods for estimating road capacity. These methods can be classified into direct empirical method and indirect empirical method (Abdullah et al., 2017). The direct empirical method made use of the observed data to directly estimate the capacity. However, in the case of the indirect empirical method, it uses the observed data and some computer software to perform simulations that involve complex simulation models. However, the capacity estimated by the simulation model may not be accurate.

Phase 2 Formation of the network graph

Before applying the maximum flow algorithm in this study, a network graph will be needed. To form a network graph, several data are needed, such as the name, direction and capacity of roads in the selected areas. The intersections are designated as the nodes of the network graph, the path that is connected between the intersections are the arcs with the direction and capacity of the road sections assigned according to the direction of the arcs. With all the nodes, arcs, directions and capacities, a directed network graph can be formed. The network is formed by the arcs and connected to the nodes (Kovalev et al., 2021). A capacitive directed network graph has been formed with the capacity obtained by the observation data. It is used to calculate the maximum flux. First, a directed condensed network graph was formulated with all edges and nodes. Each of the arcs has a non-negative capacity, $c(u,v) \geq 0$ and fluxes, $f(u,v)$ which cannot be greater than the capacity of the edge (Masadeh et al., 2017). Multiple sources and multiple sink are addressed in this study. Therefore, the network graph will have multiple source nodes, s, and multiple sink nodes, t, which are the start nodes and end points. A directed capacity network must satisfy the following conditions (Bulut et al., 2021):

First, the capacity constraint $\forall (u,v) \in E\ f(u,v) \leq c(u,v)$. The flow of edges must not exceed its own capacity.

Then the next condition is oblique symmetry, $\forall\, u,v \in V, f(u,v) = -f(u,v)$

that the net flow from u to v and from v to u must be opposite to each other.

Finally, the flow conservation constraints, $\forall u \in V: u \neq s \text{ and } u \neq t \Longrightarrow \sum_{(s,u)\in E} f(s,u) = \sum_{(v,t)\in E} f(v,t)$ To a node is zero, except for the source node and the sink node, and the flow of the source node must be equal to the flow of the sink node (Abdullah et al., 2017).

Phase 3 Maximum Flow Algorithm: Ford-Fulkerson Algorithm

The maximum throughput in a capacitive flow network is the total throughput from a source node to a sink node.

First, an augmentation path from the source node to the sink node must be found where each edge has $f(e) < c(e)$. After the formation of the augmentation path, calculate the bottleneck capacity (Masadeh et al., 2018). Finally, increase each edge and the total flow until the capacity of the receiving node reaches the maximum.

Phase 4 Max-Flow & Min-Cut Theorem

The Ford-Fulkerson algorithm was published in 1956. In 1970, Yefim Dinitz implemented the Edmonds-Karp algorithm, which is an improved algorithm over the Ford-Fulkerson algorithm. The Edmonds-Karp algorithm uses first-blast search to find augmentation paths. Next, Dinic's blocking flow algorithm is implemented and it constructs a layered graph with a breadth-first search on the residual graph before finding the augmenting paths. In 1986, the relabel push algorithm was published using the concept of preflow. It uses a local operation which allows the method to be faster in practice (Han et al., 2014). The maximum flux and minimum cut theorem is used to find the maximum flux of the capacitive directed network. The maximum amount of flux that passes from the source node to the sink node is equal to the total weight of the edges in minimum cut. $\mathrm{Max}\,\{\mathrm{val(f)}; \mathrm{f\ is\ aflow}\} = \min\{\mathrm{cap(S)}; \mathrm{s\ is\ an\ (s,t)-cut}$ (Han et al., 2014).

4. Research design

The research design framework, shown in Figure 1, shows the flow of minimizing traffic congestion problems. There are two types of congestion, namely recurrent and non-recurrent, but only recurrent congestion is discussed in this paper. Cost, capacity, time and distance were the typical parameters. However, capacity is the main parameter used in this study. The selected network was a directed capacity network with multiple sources and multiple sinks. Based on the network, the Ford-Fulkerson algorithm, i.e., the maximum flow and minimum cut theorem, was chosen to find the maximum flow and bottleneck paths (Abdullah et al., 2017).

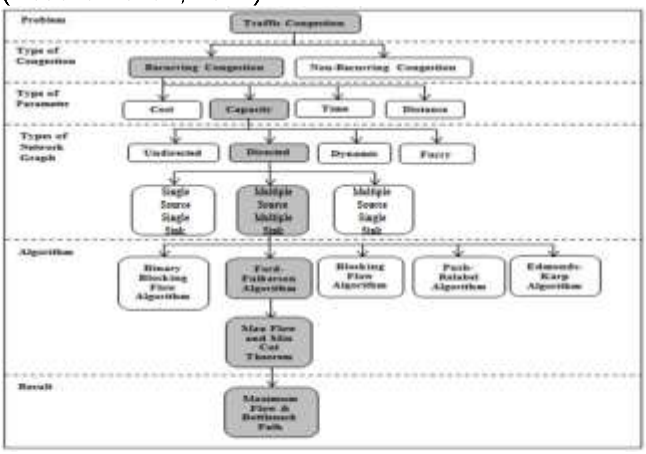

Figure 1. Research design on traffic congestion problems

5. Results and discussion

5.1. Data collection

In this study, the required data was the volume of vehicles passing through the respective selected roads. Due to the costs involved and budgetary constraints, manual traffic counting was chosen as the most appropriate method compared to automatic counting. Therefore, traffic volume counting has to be carried out at the selected intersections or roads. The tools needed for manual traffic counting were tally sheets, a stopwatch, a pen and paper.

Traffic data is collected at different time intervals, for example hourly, daily or monthly. In this study, data was collected hourly to match the road capacity estimation method. Since the data was collected on an hourly basis, a particular time interval was chosen to collect the traffic data with greater accuracy. The time intervals chosen were weekday morning peak hours, rather than weekends. The morning peak hours, between 6 and 9 a.m., were the most appropriate because of the high volume of traffic.

The direct empirical method was chosen in this study because of its lower cost, ease of implementation and better accuracy of capacity estimation results. There are three approaches in the direct empirical methods which are the path approach, the volume approach and the fundamental diagram approach. Among these approaches, the volume approach was chosen as the main approach to estimate the capacity of the selected roads. The data needed for the estimation are the road width, traffic volume, passage, speed and density.

Table 1 below shows the composition of traffic according to the different classes of vehicles passing through the network concerned. It is therefore possible to calculate the total capacity of the selected locations. In Table 1, different nodes have been assigned to the selected paths between the source node and the sink node. Each of the selected paths with the composition of different vehicle categories was displayed. The vehicles were classified as follows: cars, motorbikes, large goods vehicles (HGVs) and buses or trucks. The traffic composition in Table 1 corresponded to the maximum flow in a pre-noon peak hour interval.

Let:

- ✓ A= The column representing the numbers of the arcs;
- ✓ B= The column representing the names of the places or the names of the arcs;
- ✓ C= The column representing the sources of the arcs;
- ✓ D= The column representing the destinations of the arcs;
- ✓ E= The column representing the numbers of cars that travel on these arcs;

- ✓ F= The column representing the numbers of motorbikes that run in these arcs;
- ✓ G= The column representing the numbers of heavy goods vehicles that travel on these arcs;
- ✓ H= The column representing the number of buses and trucks that travel in these arcs;
- ✓ I= The column representing the total number of traffic on these sections.

Table 1. Traffic mix (maximum flow in a one-hour interval)

A	B	C	D	E	F	G	H	I
1	Aeroport-Mikondo	S_1	V_1	850	555	251	648	2304
2	Entrance Mikondo-Mikondo	S_2	V_1	205	110	105	440	860
3	Mikondo - Mikondo entrance	V_1	T_1	30	25	19	30	104
4	Mikondo-Indu	V_1	V_2	1020	840	400	800	3060
5	Input Indu - Indu	S_3	V_2	210	115	105	440	870
6	Indu - Indu input	V_2	T_2	100	105	60	85	350
7	Indu-Pascal	V_2	V_3	1200	1100	530	1050	3880
8	Entrance Mokali - Pascal	S_4	V_3	220	112	103	430	865
9	Pascal - Mokali entrance	V_3	T_3	210	105	105	430	850
10	Pascal-BKTF	V_3	V_4	1205	1110	530	1050	3895
11	BKTF-Bitabe	V_4	V_5	1230	1140	550	1065	3985
12	Entrance Bitabe - Bitabe	S_5	V_5	210	115	105	440	870
13	Bitabe - Entrance Bitabe	V_5	T_4	205	110	105	440	860
14	Bitabe-Kimbuta	V_5	V_6	1233	1144	553	1065	3995
15	Kimbuta-Quartier 1	V_6	V_7	1233	1144	553	1065	3995
16	Entrance Ward 1 - Ward 1	S_6	V_7	210	115	105	440	870
17	Ward 1 - Entrance Ward 1	V_7	T_5	222	112	103	430	867
18	Q1- Slaughterhouse entrance	V_7	V_8	1233	1144	556	1065	3998
19	Abattoir-Debonhomme entrance	V_8	T_6	1233	1144	558	1065	4000
20	Indu-Entry Kulumba	V_2	V_{10}	210	105	55	130	500
21	Entrance Kulumba - Indu	V_{10}	V_2	210	115	105	370	800
22	SIFORCO- Kulumba entrance	S_7	V_{10}	205	110	105	440	860
23	Entrance Kulumba - SIFORCO	V_{10}	T_7	210	115	100	125	550
24	Entrance Kulumba-Kulumba	V_{10}	V_{11}	95	100	15	50	260
25	Kulumba - Kulumba entrance	V_{11}	V_{10}	95	100	15	40	250
26	Kulumba - BKTF	V_{11}	V_4	200	115	105	370	790
27	BKTF - Kulumba	V_4	V_{11}	222	112	55	311	700
28	Kulumba - Mapela	V_{11}	T_8	210	105	55	80	450
29	Mapela - Kulumba	S_8	V_{11}	210	115	100	105	530
30	Petro Congo-Slaughterhouse entrance	S_9	V_8	200	115	105	330	750
31	Slaughterhouse entrance - Petro Congo	V_8	T_9	200	115	105	328	748

To estimate the capacities of the arcs, the flows in each one-hour interval were extracted from the morning peak hours. The peak flow allowed us to obtain the estimated capacity per hour. Similar steps were performed for the other locations, and are presented in Table 2.

Among these approaches, the volume approach was chosen as the main approach to estimate the capacity of the selected roads. The data needed for the estimation in our case are the road width and the traffic volume.

Table 2. Composition of estimated network capacities

Order	Name of the place	From	To	Capacities
1	Airport-Mikondo	S_1	V_1	4000
2	Entrance Mikondo- Mikondo	S_2	V_1	1000
3	Mikondo - Mikondo entrance	V_1	T_1	1000
4	Mikondo-Indu	V_1	V_2	4000
5	Input Indu - Indu	S_3	V_2	1000
6	Indu - Indu input	V_2	T_2	1000
7	Indu-Pascal	V_2	V_3	4000
8	Entrance Mokali - Pascal	S_4	V_3	1000
9	Pascal - Mokali entrance	V_3	T_3	1000
10	Pascal-BKTF	V_3	V_4	4000
11	BKTF-Bitabe	V_4	V_5	4000
12	Entrance Bitabe - Bitabe	S_5	V_5	1000
13	Bitabe - Entrance Bitabe	V_5	T_4	1000
14	Bitabe-Kimbuta	V_5	V_6	4000
15	Kimbuta-Quartier 1	V_6	V_7	4000
16	Entrance Ward 1 - Ward 1	S_6	V_7	1000
17	Ward 1 - Entrance Ward 1	V_7	T_5	1000
18	Q1- Slaughterhouse entrance	V_7	V_8	4000
19	Abattoir-Debonhomme entrance	V_8	T_6	4000
20	Indu-Entry Kulumba	V_2	V_{10}	1000
21	Entrance Kulumba - Indu	V_{10}	V_2	1000
22	SIFORCO- Kulumba entrance	S_7	V_{10}	1000
23	Entrance Kulumba - SIFORCO	V_{10}	T_7	1000
24	Entrance Kulumba-Kulumba	V_{10}	V_{11}	1000
25	Kulumba - Kulumba entrance	V_{11}	V_{10}	1000
26	Kulumba - BKTF	V_{11}	V_4	1000
27	BKTF - Kulumba	V_4	V_{11}	1000
28	Kulumba - Mapela	V_{11}	T_8	1000
29	Mapela - Kulumba	S_8	V_{11}	1000
30	Petro Congo- Slaughterhouse entrance	S_9	V_8	1000
31	Slaughterhouse entrance - Petro Congo	V_8	T_9	1000

The figure below shows the estimated capacities of each route in our network based on road widths and traffic volumes:

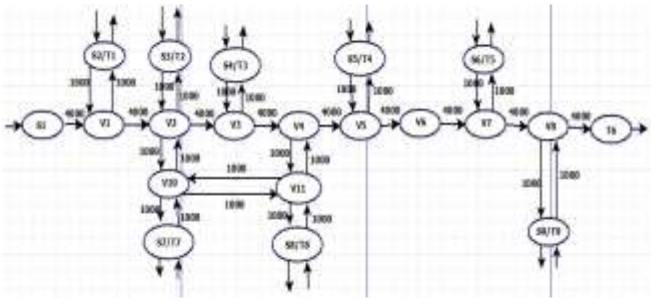

Figure 2. Graph of the network with estimated capacity

Figure 2 shows a graph of the network from the source node (N'djili Airport) to the sink node (Debonhomme) with the estimated capacity from Table 2. This figure represents a network with 20 nodes and 31 arcs with several sources and several sinks.

First type of path augmented by the Ford-Fulkerson algorithm

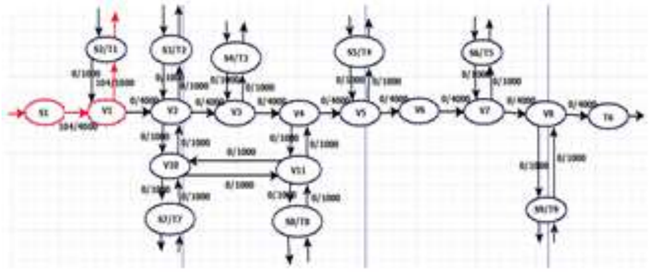

Figure 3. First augmentation path (first type**)**

The first increase path of the first type was (S_1 ,V_1 ,T_1) (red line in Figure 3) which carries a maximum flow of 104 vehicles per hour.

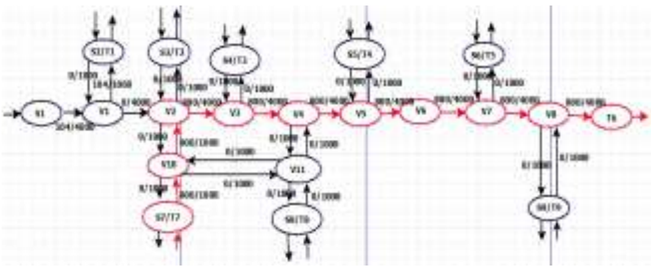

Figure 4. Second augmentation path (first type)

The second increase path of the first type started from (S_7 ,V_{10} ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6) (red line in Figure 4) and carries a maximum flow of 800 vehicles per hour.

The following table shows us a summary of all the augmented roads in the network and their maximum vehicle flows per hour.

Table 3. Summary of all augmented paths

Chain rank	Source	Well	Elements of the chain	Value
1ière Improving chain	S_1	T_1	S_1 ,V_1 ,T_1	104
2ième improving chain	S_7	T_6	S_7 ,V_{10} ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6	800
3ième improving chain	S_7	T_4	S_7 ,V_{10} ,V_{11} ,V_4 ,V_5 ,T_4	60
4ième improving chain	S_1	T_6	S_1 ,V_1 ,V_2 ,V_{10} ,V_{11} ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6	200
5ième improving chain	S_1	T_7	S_1 ,V_1 ,V_2 ,V_{10} ,T_7	300
6ième improving chain	S_4	T_7	S_4 ,V_3 ,V_4 ,V_{11} ,V_{10} ,T_7	250
7ième improving chain	S_4	T_8	S_4 ,V_3 ,V_4 ,V_{11} ,T_8	450
8ième improving chain	S_4	T_6	S_4 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6	165
9ième improving chain	S_8	T_5	S_8 ,V_{11} ,V_4 ,V_5 ,V_6 ,V_7 ,T_5	530
10ième Improving chain	S_2	T_2	S_2 ,V_1 ,V_2 ,T_2	350
11ième improving chain	S_2	T_3	S_2 ,V_1 ,V_2 ,V_3 ,T_3	250
12ième Improving chain	S_2	T_4	S_2 ,V_1 ,V_2 ,V_3 ,V_4 ,V_5 ,T_4	260
13ième improving chain	S_3	T_5	S_3 ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,T_5	370
14ième improving chain	S_3	T_9	S_3 ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_9	250
15ième improving chain	S_3	T_6	S_3 ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6	250
16ième improving chain	S_1	T_3	S_1 ,V_1 ,V_2 ,V_3 ,T_3	600
17ième improving chain	S_1	T_4	S_1 ,V_1 ,V_2 ,V_3 ,V_4 ,V_5 ,T_4	540
18ième Improving chain	S_1	T_6	S_1 ,V_1 ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_6	432
19ième improving chain	S_6	T_6	S_6 ,V_7 ,V_8 ,T_6	500
20ième improving chain	S_6	T_9	S_6 ,V_7 ,V_8 ,T_9	370
21ième improving chain	S_1	T_9	S_1 ,V_1 ,V_2 ,V_3 ,V_4 ,V_5 ,V_6 ,V_7 ,V_8 ,T_9	128
22ième improving chain	S_5	T_6	S_5 ,V_5 ,v6 ,V_7 ,V_8 ,T_6	870
23ième improving chain	S_9	T_6	S_9 ,V_8 ,T_6	750

Based on the above table, which shows the synthesis of all the augmented paths of the network and their maximum vehicle flows per hour, we can represent our road network obtained by the Ford-Fulkerson algorithm as follows:

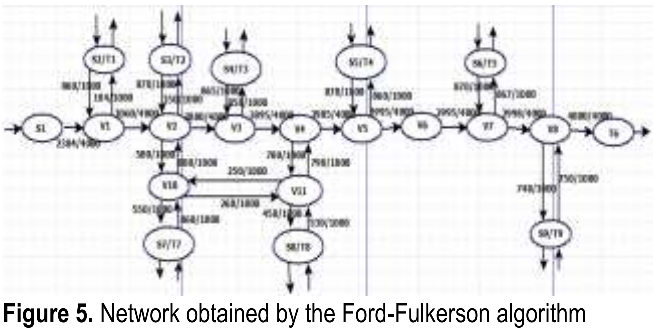

Figure 5. Network obtained by the Ford-Fulkerson algorithm

The maximum throughput of the network graph in Figure 5 is 4000 vehicles per hour. According to Figure 5, the total value of the maximum throughput is the sum of the two increase paths, i.e. the network coming from V7 and the network coming from S9 towards T6.

5.2. Max-Flow and Min-Cut Theorem

The capacity of the cut and the sum of the capacities of its arcs are identical. The bottleneck capacity which is the minimum residual capacity of any edge in the network. The cut with the smallest capacity gives the maximum flow in the capacity network.

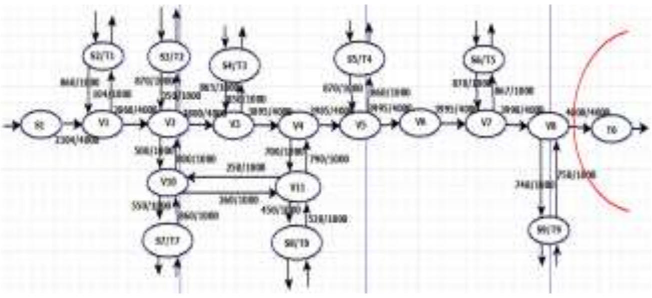

Figure 6. Minimum cross-section on the network flow

In Figure 6, the red cross-section represents the network cross-section going to the terminal node T_6, which corresponds to the maximum flow calculated by the Ford-Fulkerson algorithm. The congestion routes in the network in Figure 6 are N'djili Airport, Indu, Pascal, Bitabe, Kimbuta, Q1, Abattoir and Debonhome. The traffic planner should take into account the congestion roads to minimise traffic congestion in Tshangu.

5.3. Discussion

The Ford-Fulkerson algorithm can exactly terminate a network graph with a feasible flow. It will continue to progress further along the augmentation path if it has more eligible augmentation paths (Akter et al., 2021). It will stop if there are no eligible augmentation paths. Although in the history of maximum flow algorithm, Ford-Fulkerson is considered as one of the simplest, yet easy to use algorithms (Devi et al., 2022). Through this study on transportation problems such as traffic jams, without referring to which augmentation path was the best, different numbers of augmentation paths and different augmentation paths obtained would all give the same maximum flow value. This result is similar to that of (Gebreanenya et al., 2016), who published a paper on the application of Ford-Fulkerson algorithm to solve the maximum flow problem of airlines, and that of (Abdullah et al., ss2017) who published a paper on Using Ford-Fulkerson Algorithm and Max Flow-Min Cut Theorem to Minimize Traffic Congestion in Kota Kinabalu.

The Ford-Fulkerson algorithm can be used to calculate an optimal solution, but it is still considered an old algorithm, which gives slow results compared to other algorithms. In addition, the Max-Flow and Min-Cut theorem is an s-t cut of a network graph. It can be used to identify the bottlenecks and the maximum flow of the network graph. The cut is performed by reducing the path between s-t vertices. Different cuts have different capacities.

The cut with the minimum cutting capacity corresponds to the maximum flow of the network. This is a straightforward and simple method to obtain the maximum flow. Further study of this algorithm can be carried out in order to obtain the solution with fewer iterations and in a shorter time.

6. Conclusion

In this paper, we have exploited the Ford-Fulkerson algorithm known in graph theory to determine the maximum flow in a road traffic network. Congestion in a road network is a major problem that occurs when the volume of traffic exceeds the capacity of existing road facilities. The presence of road traffic congestion is due to the existence of a high number of vehicles on the road at the expense of the road traffic infrastructure and the high growth of the urban population. Only one road connects the city center of Kinshasa, which concentrates the main activities of the inhabitants, to the international airport of Ndjili.

The maximum throughput for the capacity network with 20 nodes and 31 arcs in the area selected in this study was 4000 vehicles per hour. The traffic planner who designed the road and transport networks has to be concerned about bottlenecks like Abattoir and Debonhomme. However, the traffic volume may change from time to time depending on the day of the week and the period of activity. Therefore, the capacity in this study will not be constant at all times. Further research is therefore suggested, especially on the part of capacity estimation where some data such as vehicle speed, road width, number of lanes, and others can be included in the capacity estimation.

In this study, the identification of the maximum flow and bottleneck path along the Lumumba Blvd between Debonhomme and Ndjili International Airport in the Tshangu district of Kinshasa was carried out. All possible routes from the different sources to the different wells were established.

The results obtained in this work prove that we are in the presence of recurrent congestion which is known as traffic congestion during the pre-noon peak hours between 6 am and 10 am which generally occurs along Lumumba Boulevard between N'djili International Airport and Debonhomme in the Tshangu district of Kinshasa.

The occurrence of these traffic jams is due to a significant increase in the number of vehicles against the limited availability of road infrastructure and the unlimited growth of the urban population in this area.

On this basis, the optimal solutions would be the construction of secondary roads, improvement of the road facilities and adequate traffic control to minimize the problem of traffic congestion in this stretch.

Otherwise, we will have two related components in this route, which will occur precisely on the Mayi ya N'djili bridge, that is between Entrée Abattoir and Debonhomme, the place where the main bottleneck is located, because of the long term overloading during the traffic jam on this bridge.

Therefore, it is in the interest of the urban authorities and road construction engineers to make good use of the results of this work.

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