Maximal Flow Of Transportation Network In Medan City Using Ford-Fulkerson Algorithm

Faridawaty Marpaung[1*], Arnita[2], Nila Sari[3]

[1,2,3] Mathematics Departement Universitas Negeri Medan, Jalan Williem Iskandar Pasar V, Medan North Sumatera Indonesia
[*]Corresponding Author :
Email: faridawaty@unimed.ac.id

Abstract.
Transportation is a major component of living, government, and social systems. Tsocio-demographic conditions influence the performance. In this study has a purpose as an investigation of an event that measures the maximal capacity of the road as a way to overcome congestion. Searching for the maximal flow based upon the graph formed using the Ford-Fulkerson Algorithm with numerous stages, namely determining the possible pathway through the source point to the main point arranged in numerous iterations by analyzing the graph formed. Then the initialization process is given by zero flow from each side of the graph, then the search for maximal flow is obtained after doing as many as 16 iterations. The residual flow results from subtracting the total number of flows by the number of flows at each iteration. The iteration will stop if no more augmenting pathway is found. Cuts will occur if the amount of flow equals the amount of capacity. Research data is in the form of public transportations in Medan and routes. The data was obtained directly from the archives of the Transportation Service in Medan City. The search for the maximal flow of the transportation network is carried out by observing the public transportation route in the city of Medan, namely the public transportation route through Jalan Jamin Ginting to Jl. Various types of public transportation traverse Williem Iskandar. Based upon the research, the maximal capacity can be exceeded through the transportation network. There are 5 types of public transportations. The pathway through City Hall - Jl. Putri Hijau and the pathway through Jl. Perintis Kemerdekaan–Jl. HM. Yamin has exceeded capacity because the types of public transportation that pass through the two roads are 15 and 9. However, the other lanes are still low, so it should divert some types of public transportation overload to empty roads.

Keywords: *Traffic Congestion, Transport Network, Maximal Flow and Ford-Fulkerson Algorithm.*

I. INTRODUCTION

The problem frequently found in traffic in big cities and other developing areas is the congestion caused by improper traffic management. Traffic volume and inadequate infrastructure lead to the severity of congestion. A certain road segment or road segment has a capacity that is not always the same as the current volume that passes through it, especially in the city of Medan.A book entitled Medan City in Figures, published by the Central Agency on Statistics in 2020 (Indonesian: Biro Pusat Statistik), states that at the end of 2018, there were 3,279.50 km of road facilities consisting of 1,750.47 km in good condition, 1,194.29 km in moderate condition, 312.28 km in damaged condition, and 22.46 km of the roads were in heavily damaged condition. These conditions may affect traffic congestion.These factors of traffic conditions and many others can be analyzed as a mathematical model of the problems [1]. The various problems can be formulated as finding a pathway between two points in an optimal graph with many specified criteria [2]. The maximal flow problem involves a directional network with a flow that carries an arc to find the maximal flow that can be sent through the network arc from some specific point S, which is usually called the source, to the second specified T point, and which is usually called the destination. This is shown by solving the maximal flow problem on Ethiopian Airlines by using the Ford and Fulkerson algorithm [3].The algorithm that solves the existing maximal flow problem involves many steps and calculations to solve the maximal flow problem due to improper selection of the augmentation pathway. Therefore, the improvement of the proposed algorithm for solving the maximal flow problem does not involve a method of labeling, and the whole process of which only needs to draw a diagram [4].

Different amounts of augmentation can achieve optimal maximal flow. The maximal flow obtained by the Ford-Fulkerson Algorithm remains in the form of integers because of all the parameters in the network graph displays the integral, so the result obtained the maximal flow remains integral. The structural Model used in transportation has a function as a weighted graph is a graph generated with real numbers. The way used to control minimal traffic and maximal flow is by minimizing the number of sides in the network and maximizing the capacity of vehicles to move through that side. Using minimal cuts for network traffic, it can lead to minimal wait times that use traffic for smooth and hassle-free traffic flow [6].Certain road sections or road segments have different capacities[7]. The traffic direction regulation carried out in the city of Medan does not take into account the large flow of vehicles, while the growth of vehicles in the city of Medan cannot be controlled. Therefore, it is necessary to analyze the vehicle network based upon the capacity of the road so that vehicles can be controlled and congestion can be avoided. This analysis is used to find the total capacity of the land transportation network, in this case, angkot (public transportation) in numerous majors in the city of Medan. The Ford-Fulkerson Algorithm network model is employed using the Matlab Software program to obtain a solution to the above problems.

II. RESEARCH AND METHOS

The Ford-Fulkerson Algorithm is a greedy algorithm that calculates the maximal value of flow in a network. As long as there is a pathway accessible at the initiating point to the end point with the same accessible capacity at all edges on the pathway, the flow will be sent along one of those pathways [8].

2.1. Research Data

The study used secondary data with an observation time of 2021, where the data were obtained by observing and analyzing from the Transportation Service in Medan City. The data were the majors/ routes of urban transportation in Medan City. The areas were passed by city transportation and the number of angkots (public transportation) per unit that runs in one day. There were 230 roads traversed by public transportation according to the route determined from the Medan City Transportation Service. The names of the roads were expressed as a vertex and the routes of the road traversed by public transportations were the edge. The public transportation route passed through Jalan Jamin Ginting to Jalan Williem Iskandar was observed in this study.In Medan City, there are two established routes for urban transportation, namely the exit and entry routes. This study observes the outgoing public transportation route through Jalan Jamin Ginting to Jalan Williem Iskandar.

Table 1. Public Transport Route Simulation

No Public Transportation	Route
54	$v_{56} - v_{95} - v_{96} - v_{162} - v_{117} - v_{70} - v_{163} - v_{164} - v_{67} - v_{68} - v_{165} - v_{14} - v_{15} - v_{26}$
104	$v_{56} - v_{94} - v_{95} - v_{96} - v_{162} - v_{117} - v_{70} - v_{163} - v_{164} - v_{67} - v_{68} - v_{165} - v_{14} - v_{15} - v_{26}$
121	$v_{56} - v_{57} - v_{58} - v_{90} - v_{23} - v_{36} - v_{37} - v_{38} - v_{24} - v_{25} - v_{17} - v_{16} - v_{26}$
11	$v_{56} - v_{94} - v_{95} - v_{117} - v_{163} - v_{164} - v_{67} - v_{68} - v_{165} - v_{14} - v_{15} - v_{26}$
67	$v_{56} - v_{94} - v_{95} - v_{117} - v_{192} - v_{70} - v_{181} - v_{182} - v_{183} - v_{130} - v_{7} - v_{9} - v_{39} - v_{26}$

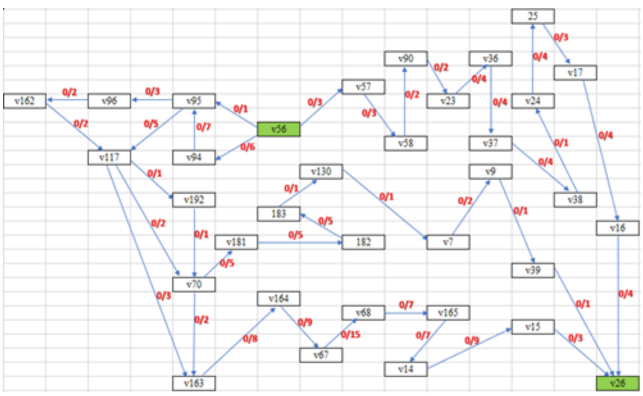

Fig 1. Public transport routes in graphic form

2.1.1 Labeling Process

Labeling is given to each edge taking into account how many types of public transportation pass from one point to another.

Table 2. Weight of each side

No	Edge	Weight	No	Edge	Weight
1	$v_{56} \rightarrow v_{95}$	1	21	$v_{23} \rightarrow v_{36}$	4
2	$v_{56} \rightarrow v_{94}$	6	22	$v_{182} \rightarrow v_{183}$	5
3	$v_{56} \rightarrow v_{67}$	3	23	$v_{67} \rightarrow v_{68}$	15
4	$v_{95} \rightarrow v_{96}$	3	24	$v_{36} \rightarrow v_{37}$	4
5	$v_{95} \rightarrow v_{117}$	5	25	$v_{183} \rightarrow v_{130}$	1
6	$v_{94} \rightarrow v_{95}$	7	26	$v_{68} \rightarrow v_{165}$	7
7	$v_{57} \rightarrow v_{58}$	3	27	$v_{37} \rightarrow v_{38}$	4
8	$v_{96} \rightarrow v_{162}$	2	28	$v_{130} \rightarrow v_{7}$	1
9	$v_{162} \rightarrow v_{117}$	2	29	$v_{165} \rightarrow v_{14}$	7
10	$v_{117} \rightarrow v_{192}$	1	30	$v_{98} \rightarrow v_{24}$	1
11	$v_{117} \rightarrow v_{70}$	2	31	$v_{7} \rightarrow v_{9}$	2
12	$v_{117} \rightarrow v_{192}$	3	32	$v_{14} \rightarrow v_{15}$	9
13	$v_{58} \rightarrow v_{90}$	2	33	$v_{24} \rightarrow v_{25}$	4
14	$v_{192} \rightarrow v_{70}$	1	34	$v_{9} \rightarrow v_{39}$	1
15	$v_{70} \rightarrow v_{163}$	2	35	$v_{15} \rightarrow v_{26}$	3
16	$v_{70} \rightarrow v_{181}$	5	36	$v_{39} \rightarrow v_{26}$	1
17	$v_{163} \rightarrow v_{164}$	8	37	$v_{25} \rightarrow v_{17}$	3
18	$v_{90} \rightarrow v_{23}$	2	38	$v_{17} \rightarrow v_{16}$	4
19	$v_{181} \rightarrow v_{182}$	5	39	$v_{16} \rightarrow v_{26}$	4
20	$v_{164} \rightarrow v_{57}$	9			

This weighting process takes about two weeks to determine how many public transportations pass through a road segment. The following displays the public transportation route from Jalan Jamin Ginting to Jalan Williem Iskandar in the form of a weighted graph.

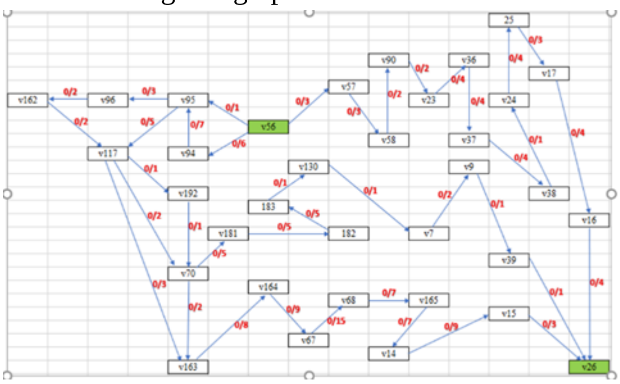

Fig 2. Labeling of transport network simulation

2.2. Ford-Fulkerson Algorithm

Let G(V,E) be the graph, and as the arc is e=(u,v), let it make c(u,v) a capacity and f (u,v) a flow. Because we want to find a maximal flow coming from source s to sink t. The Ford-Fulkerson algorithm has two main steps that are very important in its calculations. The first method is the labeling process that serves as a pathway finder for flow augmentation, namely the pathway from s to t that is f<c along all backward arcs. If the first step is the process of finding the pathway of augmenting the flow, then the second step is to change the flow accordingly. If not, then there will be no existing augmenting pathway and we get the maximal flow. The detailed step is as follows: the calculation algorithm starts with a decent flow (for example, f = 0). In general it can be stated that a node is in one of three states: unlabeled, labeled and scanned, or labeled and not scanned.When entering the first step, all nodes are not labeled. The first step is to create a labeled and unscanned source [9].

The first step. Initially, give a source label (s, l (s)=1);

Step two. Select any U node, which is labeled and not scanned (if no node is labeled and not scanned, then the current flow becomes the maximal flow).

For all nodes $v \in N(u)$(where(where$N(u)$ is the set of all the neighbor nodes of $u, i.e. (u,v) \in E$ or $(v,u) \in E). If\ v$ is unlabeled, then:

- If $(u,v) \in E$ and $f(u,v) < c(u,v)$, then assign the label $(u,+,l(v))$to node v. Where $l(v) = min(l(u), c(u,v) - f(u,v))$;
- If $(v,u) \in E$ and $f(v,u) > o$, then assign the label $(u,-l(v))$ to node v. Where $l(v) = min(l(v), f(v,u))$;

The way it's supposed to be done is to let the u be labeled and scanned; meanwhile, let the v be labeled and treated with not scanned. If the sink node t is labeled, then go to step 3, otherwise return to step 2.

Step 3. Let $x = t$, then do the following work until $x = s$.

- If the label of x is $(y,+,l(x))$, Then let $f(y,x) = f(y,x) + l(t)$
- If the label of x is $(y,-,l(x))$, Then let $f(x,y) = f(x,y) - l(t)$
- Let $x = y$

The simple Ford-Fulkerson algorithm is already implemented, but with a high time complexity, and it is a pseudo-polynomial time algorithm. By adding a flow augmentation pathway to the predefined flow contained in the graph, the maximal flow will be set in the graph. The maximal flow will be reached if in the state there are no more augmenting pathways on the flow that can be found in the graph. This however, does not give a certainty that the situation will ever be achieved, so the best thing that can be guaranteed is that the answer will be correct if the algorithm ends. If the algorithm runs forever, those streams that occur may not even converge towards the maximal flow.

III. RESULT AND DISCUSSION

The maximal flow can be found using the Ford-Fulkerson Algorithm with the following steps: Pathways that may pass through the source point to the main point can be arranged in numerous iterations.

Initialization Process

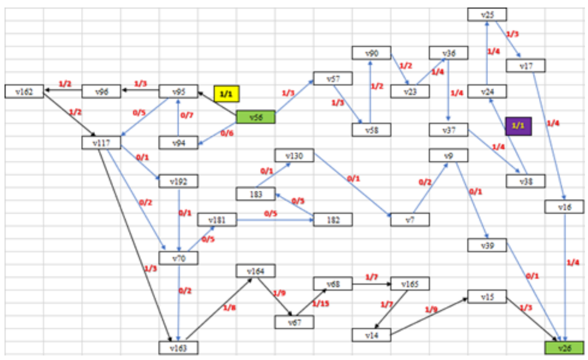

Fig 3. Simulation of the transportation network traversed

Iteration 1	**v56-v57-v58-v90-v23-v36-v37-v38-v24-v25-v17-v16-v26**
Iteration 2	**v56-v95-v96-v162-v117-v163-v164-v67-v68-v165-v14-v15-v26**
Iteration 3	v56-v95-v96-v162-v117-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 4	v56-v95-v96-v162-v117-v70-v181-v182-v183-v130-v7-v9-v39-v26
Iteration 5	v56-v95-v96-v162-v117-v192-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 6	v56-v95-v96-v162-v117-v192-v70-v181-v182-v183-v130-v7-v9-v39-v26
Iteration 7	**v56-v94-v95-v96-v162-v117-v163-v164-v67-v68-v165-v14-v15-v26**
Iteration 8	v56-v94-v95-v96-v162-v117-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 9	v56-v94-v95-v96-v162-v117-v70-v181-v182-v183-v130-v7-v9-v39-v26
Iteration 10	v56-v94-v95-v96-v162-v117-v192-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 11	v56-v94-v95-v96-v162-v117-v192-v70-v181-v182-v183-v130-v7-v9-v39-v26
Iteration 12	**v56-v94-v95-v117-v163-v164-v67-v68-v165-v14-v15-v26**
Iteration 13	v56-v94-v95-v117-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 14	v56-v94-v95-v117-v70-v181-v182-v183-v130-v7-v9-v39-v26
Iteration 15	v56-v94-v95-v117-v192-v70-v163-v164-v67-v68-v165-v14-v15-v26
Iteration 16	**v56-v94-v95-v117-v192-v70-v181-v182-v183-v130-v7-v9-v39-v26**

Fig 4. Transport network simulation in zero flow

At the initial stage the flow is considered not to exist so that a zero flow is given at each edge of the graph.

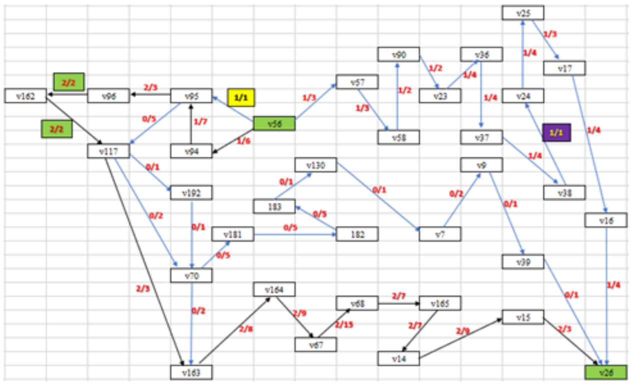

Fig 5. Simulation of the 1st iteration transport network

Iteration Process

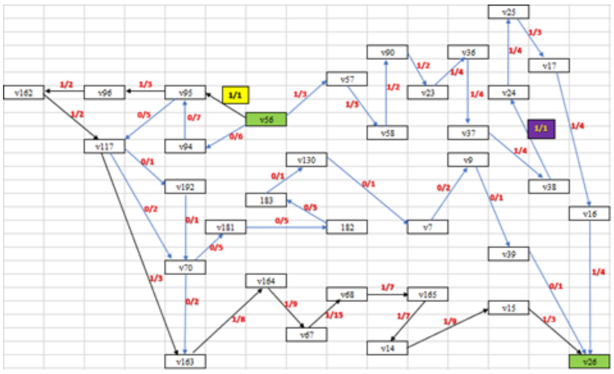

Fig 6. Simulation of the 2nd iteration of the transport network

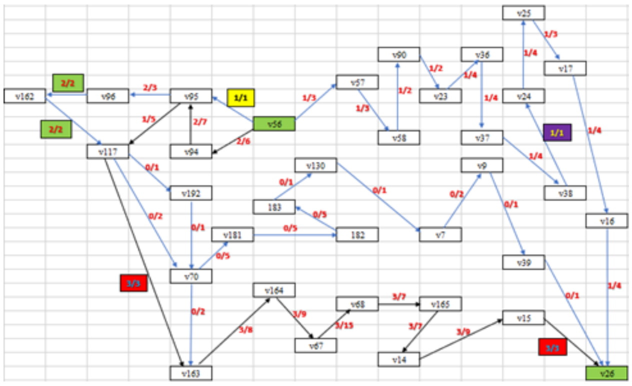

Fig 7. Simulation of the 7th iteration transportation network

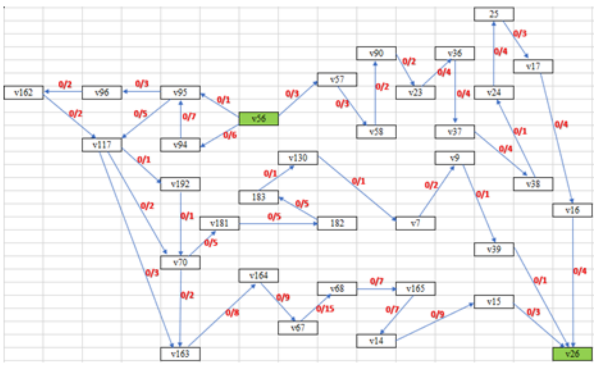

Fig 8. Simulation of the 12th iteration transport network

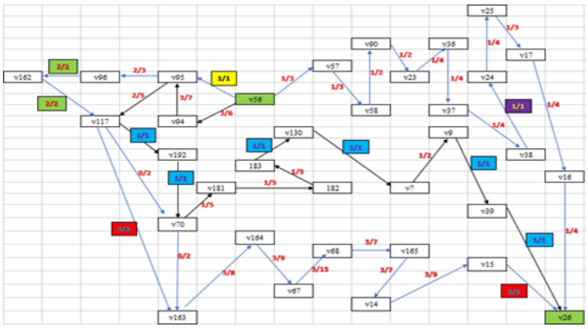

Fig 9. Simulation of the -16 iteration transport network

Based upon iteration 16, the maximal flow size is 1 type of public transportation therefore, edge v117 → v192 (Jl. S. Parman to Jl. Glugur), edge v15 → v26 (Jl. Glugur to Jl. Williem Iskandar), side v183 → v130 (Jl. Sekip to Jl. Adam Malik), side v9 → v39 (Jl. Bilal to Jl. Bhayangkara) and side v39 → v26 (Jl. Bhayangkara to Jl. Williem Iskandar) have fulfilled their maximal capacity. Because this is the last iteration, the maximal flow search process has been completed. It can be concluded that the maximal flow from the transportation network is 5 types of public transportation.

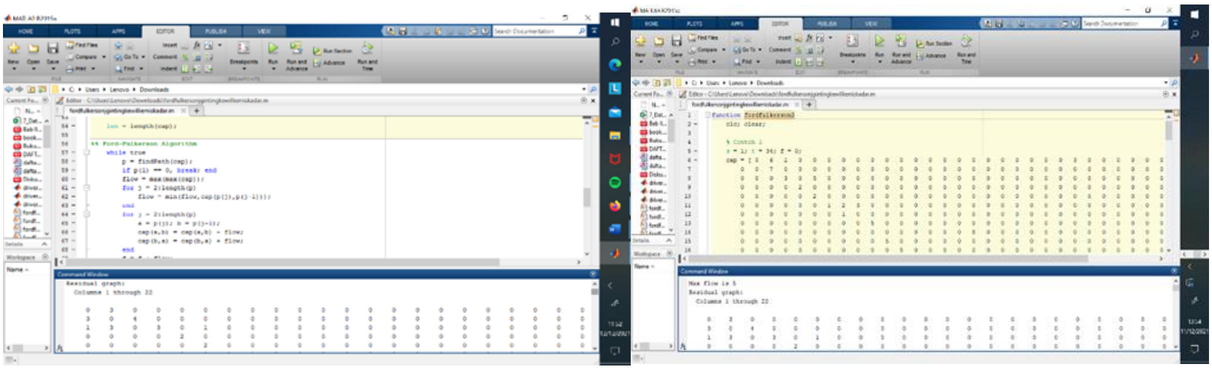

Fig 10a. Maximal flow problem output display

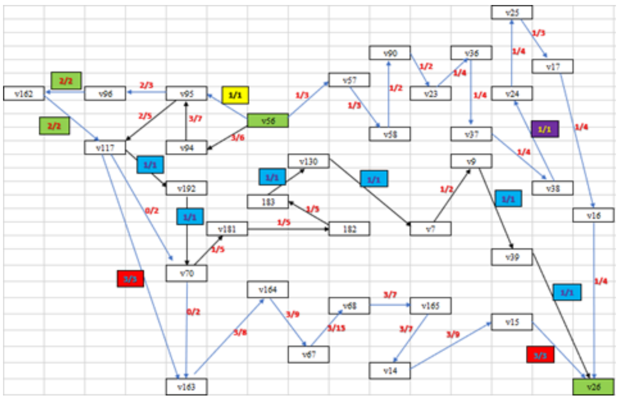

Fig 10b. Maximal flow problem output display

From Figures 10a and 10b, the maximal flow problem solving using Matlab Software is obtained. The maximal flow from the Medan City vehicle network for the public transportation route from Jalan JaminGinting to Jalan Williem Iskandar produces a maximal flow of 5 units of public transportation based upon Figure 1.

DISCUSSION

The maximum capacity (maximum flow) of the transportation network with the route of Jalan Jamin Ginting to Jalan Willem Iskandar in Medan City is 5 different types of transportation run at the same time. This is in line with the results of research [10] which states that a certain road segment or road segment has different capacity, as well as the volume of current through it. In maximizing the flow of the transportation network in Medan City, the Ford-Fulkerson algorithm gives some results in accordance with the selected transportation network, it has one source point and one destination point. Source and destination point using the Ford-Fulkerson algorithm gives accurate results in finding the path of improvement. This is in line with the results of [11] research which states that the search for maximum flow in a network that has one source point and one destination point using the Ford-Fulkerson algorithm provides accurate results in finding an increase trajectory.

IV. CONCLUSION

From the settlement analysis using Matlab Software, the maximal flow from the Medan City vehicle network for the public transportation route from Jalan Jamin Ginting to Jalan Williem Iskandar resulted in a maximal flow of 5 units of public transportation. The maximal flow of 5 units of public transport on the network means that if the network has a flow of more than 5 units there will be a side which in this case is a vehicle that exceeds the capacity of the road segment.

V. ACKNOWLEDGMENTS

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