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Research Article

Peruse Of Traffic In Educational Premises Using Max-Flow Min-Cut Theorem

Shankar D. Ugale[1*], Anjali Nanaware[2], Arundhati Vaishnav[3], Dr. Madhukar Palve,[4] Kirti Takale, Dr. Vineeta Basotia[5].

[1*]*Research Scholar, Department of Mathematics, Shri JJT University, Rajasthan, India. Email: ugaleshankarrao@gmail.com*
[2]*Student, Nutan Maharashtra Institute of Engineering and Technology, Pune, India. Email: nanawareanjali15@gmail.com*
[3]*Student, Nutan Maharashtra Institute of Engineering and Technology, Pune, India. Email: arundhatianil17@gmail.com*
[4]*Assistant Professor, Prof.Ramkrishna More Arts, Commerce and Science College Pune, India. Email: mmpalve71@gmail.com*
[5]*Research Scholar, Department of Mathematics, Shri JJT University, Rajasthan, India. Email: kirtighodekar@gmail.com*
[6]*Associate Professor, Department of Mathematics, Shri JJT University, Rajasthan, India. Email: vm.jjtu@gmail.com*

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ABSTRACT

Traffic congestion is a growing problem in urban areas around the world, and educational institutions are not immune. This research paper investigates the application of the Ford-Fulkerson algorithm to minimize traffic congestion in Samarth Vidya Sankul, Talegaon Dabhade City. The Ford-Fulkerson algorithm is a powerful tool for solving maximum flow problems in networks, and it can be effectively applied to traffic management scenarios. This paper presents a case study of Samarth Vidya Sankul, utilizing the algorithm to identify bottlenecks and optimize traffic flow within the school premises. The findings of this research can be valuable for improving traffic management not only in Samarth Vidya Sankul but also in other educational institutions and similar settings.

Keywords: Routes, Maximum Flow, Traffic, Max flow Min cut Theorem

1 Introduction:

Traffic congestion is a significant challenge faced by modern cities, leading to increased travel times, fuel consumption, and air pollution. Educational institutions, with their daily influx of students, staff, and visitors, are also susceptible to traffic congestion within their premises. This congestion can disrupt daily operations, create safety hazards, and negatively impact the overall learning environment.

This research paper explores the potential of the Ford-Fulkerson algorithm [1] to address traffic congestion issues in Samarth Vidya Sankul, located in Talegaon Dabhade City. [12] The Ford-Fulkerson algorithm is a well-established method for solving maximum flow problems in networks. [2] It works by iteratively identifying paths with available capacity in a network and directing flow along those paths until the maximum flow is achieved.

In the context of traffic management, the network can represent the road network within the school premises, with nodes representing intersections and edges representing road segments. The capacity of each edge can be defined by the maximum number of vehicles it can accommodate per unit time. By applying the Ford-Fulkerson algorithm to this network, we can identify bottlenecks (road segments with limited capacity) and optimize traffic flow by directing vehicles along alternative routes with available capacity.

This research aims to demonstrate the effectiveness of the Ford-Fulkerson algorithm in minimizing traffic congestion within Samarth Vidya Sankul. The paper will present a detailed case study, outlining the methodology, findings, and potential implications for both Samarth Vidya Sankul and other educational institutions seeking to improve traffic management within their premises.

2. Literature Review:

The intricate structure of trees finds numerous applications in graph theory, playing a crucial role in various real-world scenarios. From solving puzzles and optimizing video game mechanics to managing data flow and network efficiency, their impact is undeniable.

Max flow and Min cut theorem is used in various research paper for traffic study, water distribution, transport networks .In some research paper flow of water distribution system in specified city is studied using Max flow and Min cut theorem. Road traffic analysis is studied in paper Road traffic analysis on the congestion problem using the Ford-Fulkerson algorithm" Journal of Road and Traffic Engineering 2022. Traffic problem solution in Kota Kinabalu city in Malaysia is studied in paper Using Ford-Fulkerson Algorithm and Max Flow-Min Cut Theorem to Minimize Traffic Congestion in Kota Kinabalu, Sabah 2017. Neighboring Vehicle traffic is given in research paper (2019) "V2v-Based Method for the Detection of Road Traffic Congestion" IET Intelligent Transport Systems. Study of causes and solution on Talegaon Dabhade traffic is used in paper Traffic Congestion - Causes and Solutions: A Study of Talegaon Dabhade City, Journal of Information, Knowledge and Research in Civil Engineering 2014.Transportation of goods from one destination to another destination in minimum cost and minimum time seen in various research papers.

3. Scope:

This research investigates the potential of the Ford-Fulkerson algorithm to minimize traffic congestion within Samarth Vidya Sankul, focusing on a real-time traffic network model. We will utilize data collected from 11 key locations within the school premises to construct an accurate representation of traffic flow. The Ford-Fulkerson algorithm will be applied to this model to identify bottlenecks and propose optimized traffic flow strategies. While the study's scope is limited to Samarth Vidya Sankul and may not be directly generalizable due to variations in other institutions, it aims to provide valuable insights into the real-world application of the algorithm for traffic management in an educational setting.[3][4]

4. Research Methodology:

This research investigates the potential of the Ford-Fulkerson algorithm to minimize traffic congestion within Samarth Vidya Sankul, Talegaon Dabhade city, Pune, Maharashtra, India. To achieve this goal, we will adopt a three-pronged approach:

1. Network Model Development:

We will establish a network model that accurately represents the traffic flow within the Samarth Vidya Sankul, Talegaon Dabhade city, Pune, Maharashtra, India premises. This model will consist of 11 key locations serving as nodes in the network: Nutan Maharashtra Vidya Prasarak Mandal, Maharaja Hotel, Balasaheb Shelke Udyan gate, Nutan Maharashtra College of Engineering and Research (including its cafe), NMIET Cafe, Nutan Maharashtra College of Engineering and Technology, Navin Samarth Vidyalay, Mamasaheb Khandge English Medium School, Nutan Maharashtra Vidya Polytechnic's Workshop, and Paisa Fund Primary school.

2. Real-Time Data Collection:

To capture the dynamic nature of traffic flow, we will collect real-time data at each of the identified locations. This data will encompass counts of various categories of road users, including students, parents, cars, bikes, buses, trucks, and rickshaws. By gathering such comprehensive data, we can ensure an accurate representation of the traffic volume and composition within the school environment.

3. Algorithm Implementation and Analysis:

We will utilize the Ford-Fulkerson algorithm on the developed network model, incorporating the real-time traffic data. This algorithm will help us identify bottlenecks in the network, which are locations experiencing significant traffic congestion. Based on these findings, we will propose optimized traffic flow strategies specifically tailored to Samarth Vidya Sankul's unique traffic patterns.

By combining these steps, this research aims to identify practical solutions for mitigating traffic congestion within the school premises, potentially improving traffic flow and enhancing the overall experience for students, staff, and visitors.

5. Results and Discussion:

Transport Network:

Imagine a transportation network like a road system. This network can be mathematically represented using a special type of graph called a weighted directed connected graph, also known as a transport network. Here's a breakdown of its key characteristics:

Structure:

- **No loops:** Think of loops as dead ends in the network, which are not allowed. Traffic should flow smoothly, not circle back on itself.

- **Single source and sink:** There's only one starting point (source) where traffic originates, and one endpoint (sink) where it all converges. Imagine the source as the "origin station" and the sink as the "destination station."
- **Non-negative edge weights:** Edges represent road segments, and their weights represent the capacity of each road, indicating how much traffic it can handle. Similar to a bridge with a weight limit, the capacity ensures smooth traffic flow without exceeding the road's capabilities.

Flow of Traffic:

- **Limited by capacity**: The amount of traffic flowing through a road (edge) cannot exceed its capacity, similar to following the weight limit on a bridge.
- **Conservation of flow:** Except for the source and sink, the incoming and outgoing traffic at any point in the network must balance out. Think of it as a traffic junction where cars entering and leaving must be equal.
- **Flow value:** The total amount of traffic flowing through the network is calculated by considering the incoming traffic minus the outgoing traffic at all points except the source and sink.

Edge States:

- **Saturated edge:** When the traffic flowing through an edge reaches its full capacity ($\Phi(i, j) = W(i, j)$), it's considered saturated. Imagine a road completely packed with vehicles, unable to accommodate any more traffic.
- **Unsaturated edge:** When the traffic flowing through an edge is less than its capacity ($\Phi(i, j) < W(i, j)$), it's considered unsaturated. Think of a road with some available space for additional vehicles.

Maximum Flow:

The goal is to find the maximum flow within the network. This represents the highest volume of traffic that canflow smoothly through the network without exceeding any road's capacity.

Cuts and Separation:

A cut in the network is a group of edges separating the source from the sink. Imagine drawing a line across the network, dividing it into two sections. One section will contain the source, and the other will contain the sink.[5]

Max-flow Min-cut Theorem:

Imagine a bustling school campus during peak hours. Students, parents, and staff navigate various routes, creating a complex traffic flow network. To understand and optimize such networks, we turn to a powerful tool: The Ford-Fulkerson algorithm.
Developed by L.R. Ford and D.R. Fulkerson in 1956, this algorithm tackles the maximum flow problem: finding the highest volume of traffic that can flow between a source (entry point) and a sink (exit point) in a network, while respecting capacity constraints on each route (road segments).

Here's how the Ford-Fulkerson algorithm works:

1. **Network Setup:** We represent the network as a directed graph with nodes representing intersections and edges representing roads. Each edge is assigned a capacity, indicating the maximum number of vehicles it can handle.

2. **Initial Flow:** We start with zero flow on all edges.

3. **Finding an Augmenting Path:** We search for a path from the source to the sink where the available capacity (remaining capacity) on each edge is positive. This path is called an augmenting path. Imagine finding a route where each road section has some space for additional vehicles.

4. **Increasing Flow:** If an augmenting path is found, we increase the flow along all edges in the path by the minimum available capacity along the path. This is similar to sending the maximum number of vehicles possible without exceeding the bottleneck (least available capacity) on the path.

5. **Repeat Steps 3 and 4:** We keep searching for augmenting paths and increasing flow along them until no such path can be found. At this point, we have reached the maximum flow through the network.
   Think of the algorithm as a strategic traffic planner. It identifies routes with available capacity, allocates traffic efficiently, and avoids overloading any road segment.

Flow chart of Ford and Fulkerson algorithm

This flowchart outlines the steps involved in the Ford-Fulkerson algorithm for finding the maximum flow in a flow network:

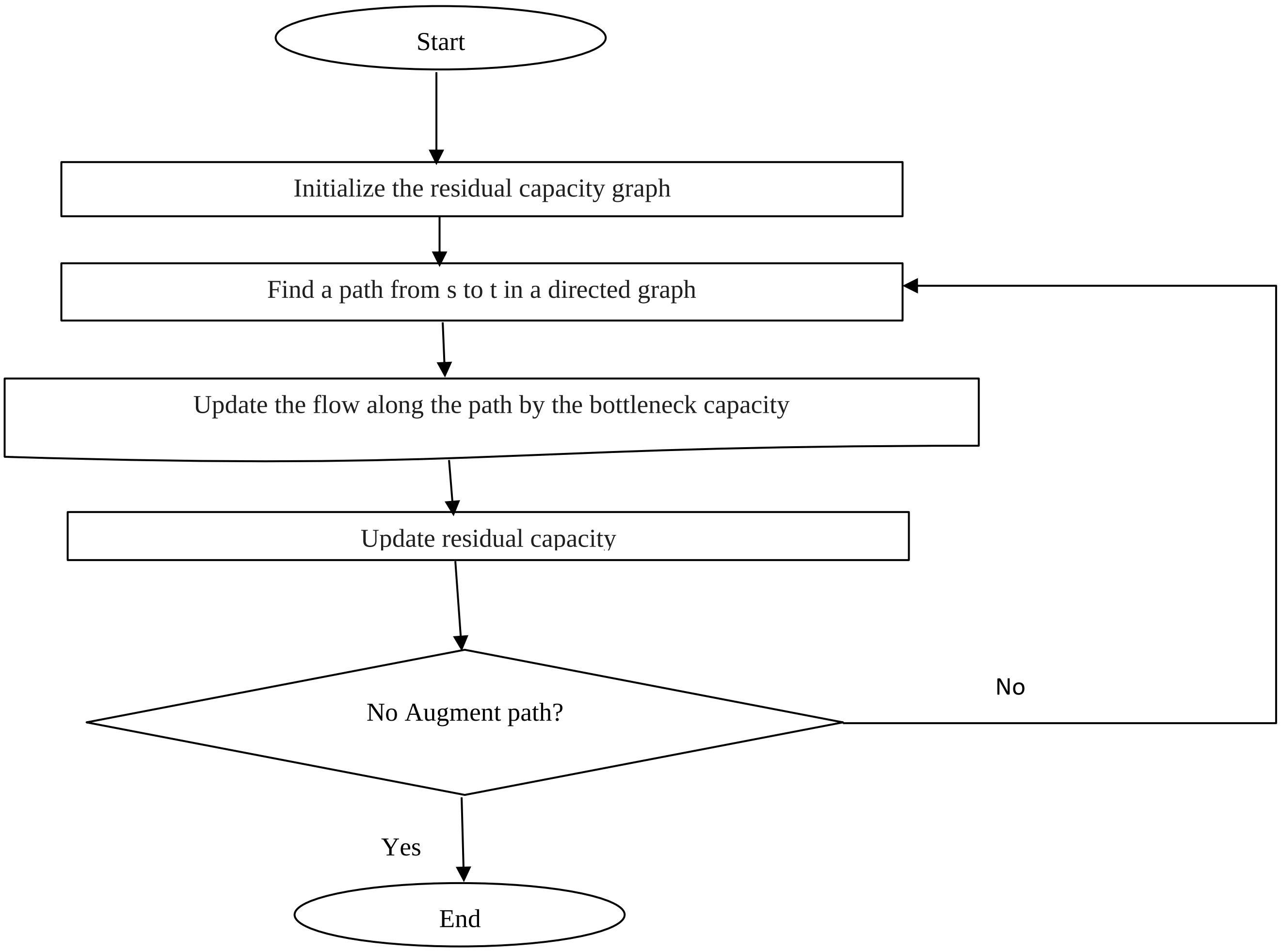


Fig 1 : Flow chart of Ford and Fulkerson algorithm

Case Study

Traffic congestion in Samarth Vidya Sankul

Our observations at Samarth Vidya Sankul revealed significant traffic congestion. To identify the most heavily congested routes, we employed the Ford-Fulkerson algorithm.

Data collection

We established a network model that accurately represents the traffic flow within the school's premises. This model will consist of 11 key locations serving as nodes in the network: Nutan Maharashtra Vidya Prasarak Mandal Gate, Maharaja Hotel, Latis society, Balasaheb Shelke Udyan gate, Nutan College of Engineering and Research, NMIET Cafe, Nutan Maharashtra Institute of Engineering and Technology, Navin Samarth Vidyalay, Mamasaheb Khandge English Medium School, NCER's Workshop, and Paisa Fund Primary School.
To simplify visualization and enhance clarity, we assigned alphabet labels to each location (vertex) in the graph:
A - Nutan Maharashtra Vidya Prasarak Mandal Gate
B - Maharaja Hotel
C - Latis society
D - Balasaheb Shelke Udyan gate
E – Nutan College of Engineering and Research (NCER College)
F – NMIET Cafe
G – Nutan Maharashtra Institute of Engineering and Technology (NMIET College)
H – Navin Samarth Vidyalay
I – Paisa Fund Primary School

J – NCER Workshop
K –Mamasaheb Khandge English Medium School

Capacity Estimation

To account for different vehicle types and their impact on traffic flow, we utilized Passenger Car Unit (PCU) equivalents. This allows us to convert the number of cars, autos, trucks, buses, and motorcycles into a standardized unit, enabling us to calculate overall traffic flow more accurately.
By employing this network model with PCU equivalents, we can effectively analyze traffic patterns within the school grounds. This will provide valuable information for optimizing traffic flow and potentially improving safety and efficiency.
We have estimated the capacity of the road manually by counting the no of vehicles in the peak hour in the morning. We have taken the readings of 5 minutes of the peak hour and then multiplied the result by 12 to get the desired result. [6]

PCU equivalent factor for different vehicles:

Vehicle type	PCU
Passenger car, tempo, auto-rickshaw, jeep, van, agricultural tractor	1.0
Truck, bus, agricultural tractor with trailer	3.0
Motorcycle, scooter, and cycle	0.5
Cycle-rickshaw	1.5

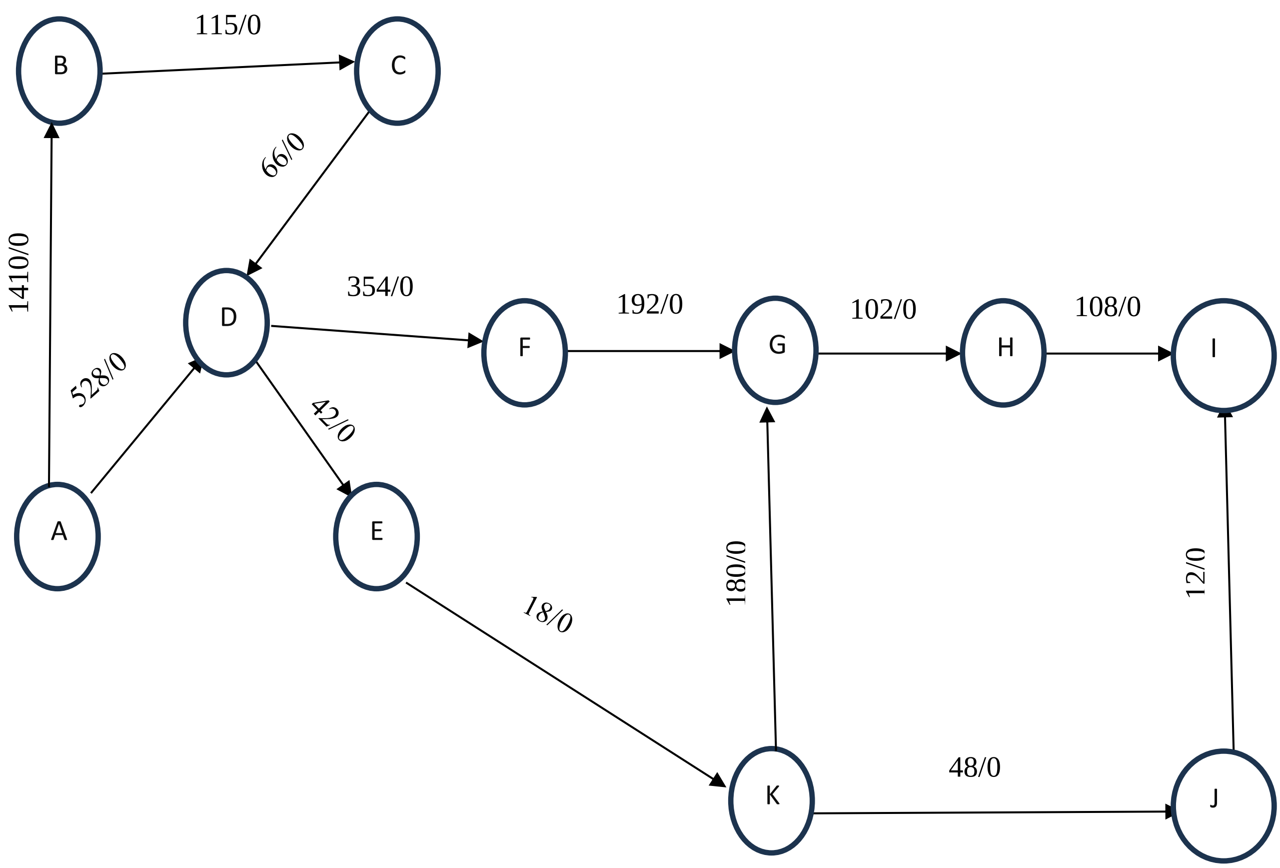
Table 1: PCU equivalent factor for different vehicles

No	Location Name	From	To	Car, Tempo, Auto	Bus, Truck, Tractor	Two Wheeler	Hum ans	Calcul ation	Total Capacity in PCU
1	NMVP main gate to Balasaheb Shelke Udyan gate	A	D	9	5	40	23	44	528
2	Balasaheb Shelke Udyan gate to NMVP main gate	D	A	8	6	36	15	44	528
3	Balasaheb Shelke Udyan gate to NCER College	D	E	0	0	7	15	3.5	42
4	NCER College to Balasaheb Shelke Udyan gate	E	D	0	0	0	3	0	0
5	Balasaheb Shelke Udyan gate to cafe	D	F	8	5	13	20	29.5	354
6	cafe to Balasaheb Shelke Udyan gate	F	D	5	0	18	5	14	168
7	Cafe to NMIET College	F	G	1	3	12	41	16	192
8	NMIET College to Cafe	G	F	0	0	3	9	9	108
9	NMIET College to Mamasaheb Khandge English Medium School	G	K	5	4	14	10	24	288
10	Mamasaheb Khandge English Medium School to NMIET college	K	G	6	1	12	4	15	180
11	NMIET college to Navin Samarth Vidyalay	G	H	1	0	15	5	8.5	102
12	Navin Samarth Vidyalay to NMIET college	H	G	0	0	7	2	3.5	42
13	Navin Samarth Vidyalay to Paisa Fund Primary School.	H	I	5	0	8	15	9	108
14	Paisa Fund Primary School to Navin Samarth Vidyalay	I	H	4	1	6	7	10	120
15	NMVP Main gate to Maharaja hotel	A	B	38	14	75	5	117.5	1410
16	Maharaja hotel to NMVP Main gate	B	A	60	17	70	7	146	1752
17	Balasaheb Shelke Udyan gate to Latis society	D	C	3	0	20	10	13	156
18	Latis society to Balasaheb Shelke Udyan gate	C	D	2	0	7	0	5.5	66
19	NCER College to Mamasaheb Khandge English Medium School	E	K	0	0	3	350	1.5	18
20	Mamasaheb Khandge English Medium School to NCER College	K	E	0	0	3	350	1.5	18
21	Mamasaheb Khandge English Medium School to NMV Polytechnic's Workshop	K	J	1	0	6	350	4	48
22	NMV Polytechnic's Workshop to Mamasaheb Khandge English Medium School	J	K	1	0	6	350	4	48
23	NMV Polytechnic's Workshop to Paisa Fund Primary School.	J	I	0	0	2	15	1	12
24	Paisa Fund Primary School to NMV Polytechnic's Workshop	I	J	0	0	1	9	0.5	6
25	Maharaja hotel to Latis society	B	C	4	1	5	3	9.6	115
26	Latis Society to Maharaja hotel	C	B	2	0	3	4	3.5	42

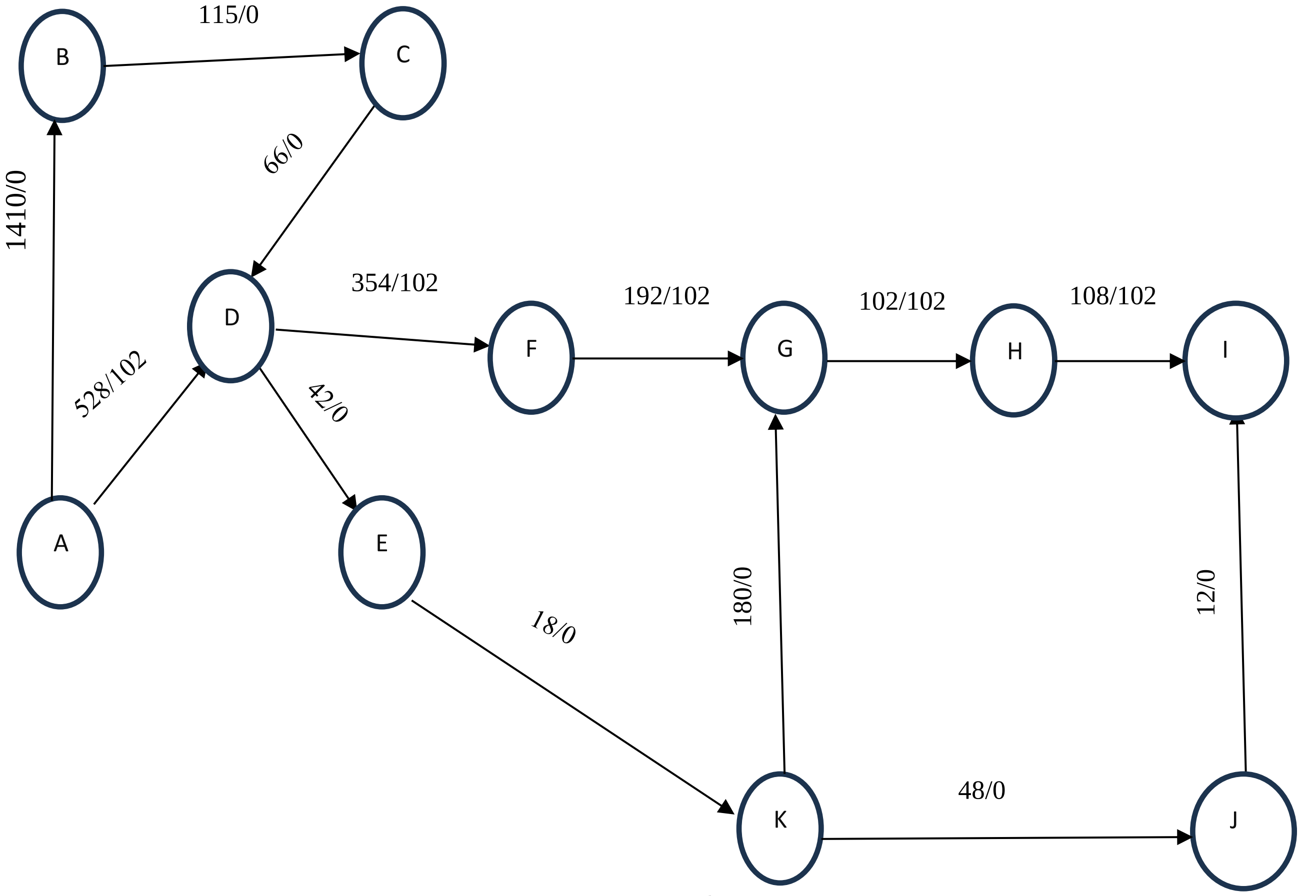
Table 2: Capacity estimation for selected locations

In above table the maximum capacity is 1752 vehicles per hour denoted by yellow color and minimum capacity is 0 denoted by green color.
We consider Nutan Maharashtra Vidya Prasarak Mandal Gate as a source and Paisa Fund Primary School as a sink for traffic calculations.

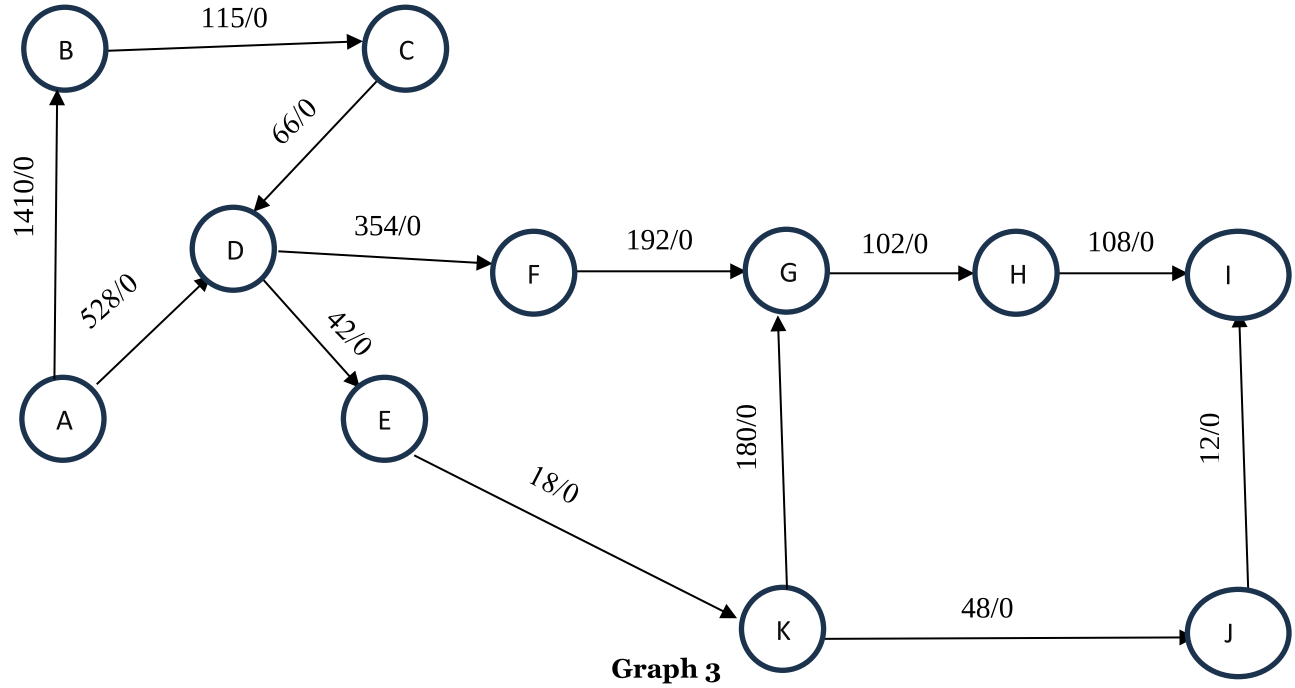
Graphical representation of Samarth Vidya Sankul.



Graph 1



Graph 2



Graph 3

Augmenting path	Bottleneck capacity
A-D-F-G-H-I	102 Vehicles per hour
A-D-E-K-J-I	12 Vehicles per hour

Table 3: Augmenting path

Max Flow: 114 Vehicles per hour
Min cut: 102+12=114 shown by blue line which is equal to maximum flow.

6. Conclusion

This research paper gives the potential application of the Max-flow Min-cut Theorem to optimize traffic flow within Samarth Vidya Sankul's premises in Talegaon Dabhade city,Pune Maharashtra, India. By constructing a real-time network model encompassing key locations and utilizing data on students, parents, vehicles, and pedestrian movement, we intent to identify bottlenecks and propose efficient traffic flow strategies. [6][7]
The maximum flow turned out to be 114 vehicles per hour when the source was taken as Nutan Maharashtra Vidya Prasarak Mandal Gate and sink was taken as Paisa Fund Primary School. This research work also shows the Bottleneck path is Nutan Maharashtra Institute of Engineering and Technology (NMIET College) to Navin Samarth Vidyalay. This approach can contribute to:

Reduced Traffic Congestion: Implementing optimized traffic flow strategies based on the algorithm's recommendations can significantly reduce congestion within the school premises, improving overall traffic flow and safety.

Enhanced Safety: Mitigating congestion points can minimize the risk of accidents involving students, parents, and staff within the school grounds.

Improved Efficiency: Optimized traffic flow can lead to increased efficiency in student movement, staff operations, and overall school logistics.
However, it's important to acknowledge the limitations of this study. Our diligent search focused on a theoretical application, and further investigation is needed to implement the proposed strategies in a real-world scenario.

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