# Quickest Path Selection Towards the Destination in Urban Environment

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***Abstract*****—** For the last few decades most of the world population is heading to the urban environment that is directly effecting the every aspect of the life. The pace of increasing vehicles is greatly higher than the expansion of the road network infrastructure in the urban areas. This causes severe traffic jams and increases the time a car stays on the road. Therefore, high carbon emissions pollute cities and degrade the quality of human life. In this paper authors focus on the quickest path selection algorithm by means of considering the passing time of each junction using a weighted graph. The experimental results show that our method is more efficient than other method.

***Keywords—traffic optimization; traffic flow; soot; traffic distribution;***

## I. INTRODUCTION

Cities have been the hubs of governmental decision-making and commercial development as well as the rearing ground for technological and cultural advancement. For last two decades, the population dwelling in urban has surpassed the population in rural. This is the first time in human age. It is predicted that urban population will reach to the sixty percent of the world's population by 2030 [1]. Due to the rapid growth in population, urban areas are struggling to revamp their groundwork.

The abrupt population growth instigated the rigorous devastation of habitations such as higher consumption of natural resources, glut noise, fine dust and air pollution, and elevating hazardous in the urban dwellers. For better urban planning some of the work has been done by using sensor network technologies, Internet of Things, and Social Internet of Things, [2]–[4]. The most important components in smart cities are the traffic controlling and travel information system for effectual management and optimum traffic flow. This research purely focuses on the vehicular traffic optimization or more precisely the fastest route finding algorithm in an urban environment as well as in smart cities. Although this research is worthy for all environments but we will broadly focus on the urban areas road network traffic issues and their solution.

To manage and control the traffic flow, the existing states of the road traffic needs to be gathered. Situations of the vehicular traffic can be defined using speed, flow and density on an explicit section of the road. The path length depends on the geometry of the road network. A diverse road traffic and traffic flow models are commonly used for assessing the vehicular traffic situations. The Intelligent Transportation system is very important issues throughout the world. Moreover communications networks and computers are significantly taking part in advancement of the road network, vehicles and traffic flow. Various algorithms have been studied so far, but a new approach is needed to select the right path for the road environment.

Every year millions of new vehicles are entering to the road, which directly effects on the traffic environment and causes the worst traffic jam situations. To tackle this issue, all countries try to create new roads or expand existing roads. But utilization of the roads is yet a big hurdle in tackling the problem.

In this research we focused on the urban road network and proposed an algorithm which find the fastest route towards the destination. Our algorithm considers the traffic on the roads and the maximum attainable speed of the road (e.g., varies with respect to the road type). Despite of focusing on the shortest path, proposed algorithm choose the path at which vehicle can attain the maximum speed limit and optimum flow. Which reduces the travel time, time span in traffic jam, noise and soot on the road network. Besides, our algorithm competently utilize the roads network in efficient way.

The rest of the paper follows the sequence as: Brief literature review based on existing techniques i.e. Ant Colony Optimization, Swarm Optimization, Hybrid Ant Colony Optimization, Dijkstra algorithm and Smart Traffic Distribution Ant Colony Optimization algorithm has been described in section 2. Section 3 presents the analysis of vehicular traffic. Our proposed scheme and explanation are in section 4. Section 5 shows the experimental results. Section 6 concludes the research work and future work.

## II. LITERATURE REVIEW

Ant Colony Optimization (ACO) algorithm has been suggested by "Marco Dorigo" in 1992 [5], [6]. ACO ascertains the competency in solving *NP*-hard problems and usually provides solutions in abridged time span i.e. Travels Salesman, Scheduling, the Quadratic Assignment, and road traffic routing optimizations [7], [8], respectively. Therefore, Ant colony optimization does not cares to the problems that have optimal results which can be solved with other techniques. The ACO algorithm works like the way ants find food. The ants emit a liquid substance known as a pheromone while searching for food. The substance contains specific information, and other ants follow it. In other words, the other ant follows the path of the front ant.

The released pheromone will dry up in a short period of time, reducing the density of substances that attract ants. However, as the following ants continue to release the pheromone, they can easily track the position of the ants in the lead. Ant colony algorithm does not guarantee finding optimal solution in all the cases but finds the shortest path in routing problems. ACO does considers the path length but does not considers the travel time and congestion factor. If we find the shortest route without considering travel time and congestion factors, it will cause serious traffic congestion. As a result, it takes longer to get to the destination.

The process of ACO completes in four phases [4]. In first step, ants randomly scatter on feasible nodes near the nest and deposit pheromone on each path. In second step, The instinctive act of the ant who searches for food at the head is similar to the stochastic choice. In third step, the other ants follow the pheromones deposited by the leading ants. In fourth step, after completing the specific loop count, the algorithm gets terminated. Dynamic problem solving by using ACO is [9], and dynamic route optimization has been done by using ACO [10]. ACO is also used to design an algorithm for dynamic automobile pathfinding problem for the purpose of visiting a group of customers in the least time by a fleet of automobiles [8]. For dynamic-vehicle routing, a hybrid technique has been introduced by L. Joon-woo et al. [11].

The improved ACO algorithm by the path crossover technique solves the deficiencies of the ACO algorithm. The previous algorithm is not easy to obtain a smooth path and takes a long time to navigate the optimal path compared to other path planning methods. The path crossover is the two-point crossover path that the ants found. The best path is saved and compared with the new path each time. When comparing and exchanging two parts, the best part is to update the best path. In addition, compared with the previous algorithm a modified pheromone update rule was proposed. The best way to rank lists is introduced. The best path is the result of path crossing and is stored for pheromone field updates as well as path crossovers. The best route is updated each time and the best route is getting better over time. The greatest amount of pheromone is placed in the unit length of the optimal path when the converged pheromone field is updated [11].

Path optimization is the most common method to solve vehicular traffic optimization and Dijkstra [12] has introduced a static algorithm to search the shortest route. That algorithm does not considered the other factors like traffic congestion, vehicle accident, or average speed of vehicles. Therefore, it is not practical enough in real traffic environment. To optimize the path, we need to update the real-time traffic information and make a new method.

## III. Analysis of the Vehicular Traffic Jam

In recent years, due to the increase in urban population, the amount of road traffic has increased highly, and the urban residential environment has been rapidly deteriorating. According to the report, China is the biggest producer of vehicles in the world. Fig. 1 shows the production of passenger cars and commercial vehicles in last one decade only in china [13]. As the number of vehicles increases, the congestion of the roads is also increasing.

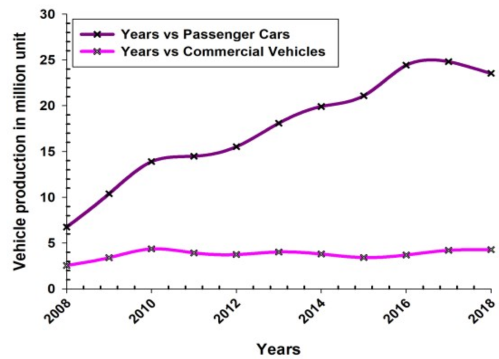


Fig. 1. Vehicle production in China

Vehicular data analysis has been performed to observe the traffic flow, density, congestion etc. on the roads. Open source vehicular traffic dataset is taken from the department for transport (DfT), UK [14]. Hourly traffic flow has been examined in one week in UK. It is observed from 6:00 am to 9:00 pm, from 5:00 pm to 8:00 pm, at peak times with the most traffic on the road. Fig. 2 depicts the detailed information of the road situation for each day. The traffic flow on Saturday and Sunday is quite different than working days. Seoul, Tokyo, Shanghai, Beijing, Delhi, and many other capital cities of each country as well as metropolitan cities are facing the same issues.

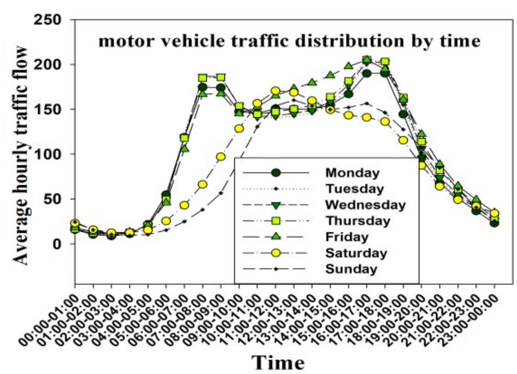


Fig. 2. Average hourly traffic flow w.r.t hours

But all the government in the world is trying to solve problems in a wide range of various ways. The road infrastructure and different means of traffic have been used to tackle the problem. But, the pace of constructing roadways is significantly lower than the ratio of incoming cars on the roads every year.

Rapidly increasing traffic volume on the roads is the primary reason of congestion. Moreover uneven traffic distribution and miss-utilization of the roads are also a big issue. Most of the drivers around the world they follow the shortest path to the destination without knowing the traffic situation and road condition which cause the heavy traffic jam. More precisely the traffic jams is occurred in the morning and evening rush hours. Fig. 3 shows the average delay per every 10 vehicles with respect to the peak hours.

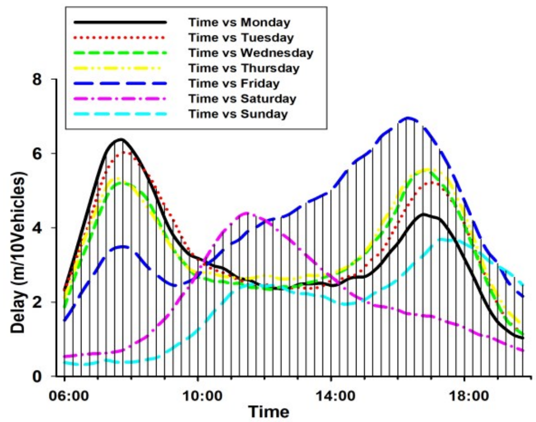


Fig. 3. Average delay time in peak hours

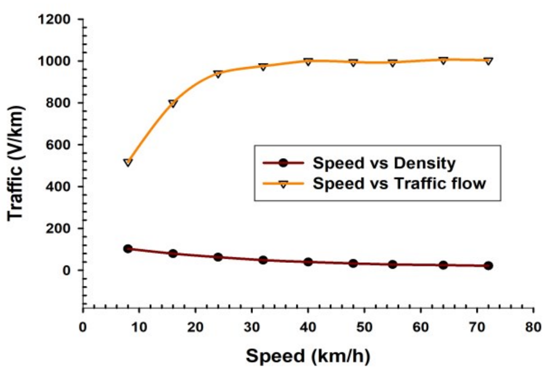


Fig. 4. Speed, traffic flow and density relation

Fig. 4 presents the traffic flow and density with respect to the speed [15], where speed and traffic flow are directly proportional to each other while speed and density are inversely proportional. If you avoid traffic congested roads and find low-traffic roads and drive for the shortest distance to your destination, you will be able to increase the efficiency of the road network and reach your destination in the shortest time.

## IV. Proposed Work and Explanation

This research focuses on the vehicular traffic optimization in urban environment, therefore we use an exemplary road network shown in Fig. 5. Equation(1) defines the road network.

$$Ǵ = (Ń, Ę) \quad (1)$$

Here $Ń = (ń_1, ń_2, ń_3 \ldots ń_n)$ represents nodes i.e. cities or junctions on the road network while Ę symbolizes the edges i.e. roads, or path. From now on, nodes, cities, and junctions will be used interchangeably, likewise edges, roads and path.

Fig. 5 is an emblematic setup of urban environment road network which is standard in all over the world but known with different road names (e.g. Express way, freeway, arterial etc.).

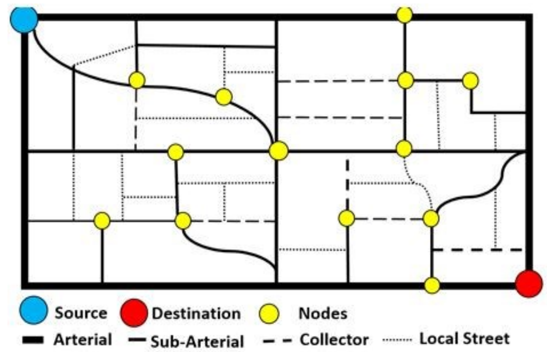


Fig. 5. Urban Road Network Scenario

All roads have different characteristics and uses, depending on the type, as shown in the table. 1 [16].

TABLE I. URBAN AREA ROAD TYPES AND CHARACTERISTICS

| **Features** | **Road Types** | | | |
|---|---|---|---|---|
| | ***Arterials*** | ***Sub-Arterials*** | ***Collectors*** | ***Subhead*** |
| Speed Limit | 45~120 | 30~80 | 30~60 | <40 |
| Side road | interchange | 0~2/km | 2~4/km | >6 |
| Signals | No | 2 | 4 | 6 |
| Purpose | Heavy traffic | Access main area | All access | All access |

Each road has different capacity depends on the carriageway. Table. 2 shows the recommended capacities of the roads with respect to the number of the carriageway.

TABLE II. CAPACITIES OF URBAN ROADS W.R.T CARRIAGEWAY AND ROAD TYPE

| **Carriageway type** | **Road Types** | | |
|---|---|---|---|
| | ***Arterials*** | ***Sub-Arterials*** | ***Collectors*** |
| 2-Lane (one way) | 2400 | 1900 | 1400 |
| 2-Lane (one way) | 1500 | 1200 | 900 |
| 3-Lane (one way) | 3600 | 2900 | 2200 |
| 4-Lane (one way) | 3000 | 2400 | 1800 |
| 4-Lane (one way) | 3600 | 2900 | - |

| | | | |
|---|---|---|---|
| 6-Lane (one way) | 4800 | 3800 | - |
| 6-Lane (one way) | 5400 | 4800 | - |
| 8-Lane (one way) | 7200 | - | - |

Every road network has a different environment and traffic regulations. Like, speed limitations, allowed vehicles, number of link roads, number of signal lights, etc. The climate change, heavy rain, snow, fog, thunder storm etc. directly affect the traffic flow. Some sporadic mega events also cause congestion for a particular time period. Among all reasons, undoubtedly, miss-utilization of the roads is one of the biggest reasons of traffic congestion. In this research we focused on finding the quickest path to reach to the destination. Our algorithm uses the current situation of the road network appropriately to obtain maximum traffic flow avoiding congestion. Our algorithm uses a list of parameters related to the road conditions given in the table below in Table. 3.

TABLE III. SYMBOLS LIST USED IN MATHEMATICAL WORK

| Symbols | Descriptions |
|---|---|
| N | junctions or nodes |
| E | roads or edges |
| n | number of nodes where, (i, j ϵ n) |
| ď'i,j | road section from i to j |
| Ţi,j | traffic on the section i to j |
| Ķi,j | capacity of the section i to j |
| Ĉi,j | congestion on the section i to j |
| ρi,j | density on the section i to j |
| Şi,j | vehicle speed on the section i to j |
| ŠL | speed limit (i.e. we assumed it is fix 60km/h) |
| ţi,j | time taken to pass the section i to j |
| Ťt | total time travel to the destination |

The proposed work calculate the traffic, distance and attainable speed on the road and then find the quickest path to the next junction. If there is a single road, the algorithm chooses the path. If there are multiple paths, the algorithm chooses the path taking into account the speed and path length. The traffic density can be check on the roads by using Equation. 2. Free flow, Normal flow and Traffic jam are the situations of traffic calculated by speed limit divided by current speed on the junction. $Ţ_{i,j}$ = 1 if speed limit is less than or equal to the current maximum speed on the particular section. $Ţ_{i,j}$ = infinite if the ratio of speed limit and current speed is greater than 10.

$$\rho_{ij} = \begin{cases} \mathit{Free\ flow} & 1 & \mathit{if}\ \frac{Š_L}{Ş_{ij}} \le 1 \\ \mathit{Normal\ flow} & \frac{Š_L}{Ş_{ij}} & \mathit{if}\ 1 < \frac{Š_L}{Ş_{ij}} < 10 \\ \mathit{Traffic\ jam} & \infty & \mathit{if}\ \frac{Š_L}{Ş_{ij}} > 10 \end{cases} \tag{2}$$

The time taken for the vehicle to cross from the intersection i to the intersection j which is a specific section of the road, can be calculated by the following Equation 3.

$$ţ_{i,j} = \frac{d'_{i,j} * \rho_{i,j}}{Š_L} \tag{3}$$

Traffic capacity or the road capacity i.e. vehicles per hour is maximum density that a road can accommodate for specific speed without any delay. Using Equation 4 we can calculate the theoretical capacity of the roadway. The congestion factor calculated by the Equation. 5.

$$Ķ_{i,j} = (1760 * Š_L) / \text{headway} \tag{4}$$

$$Ĉ_{i,j} = \rho_{i,j} / Ķ_{i,j} \tag{5}$$

$Š_L$ is the fixed vehicular speed kilometre per hour while, headway is the distance the front of one vehicle to the front of the next vehicle in the traffic lane. The general roadway capacity can be seen in Table. 4. Total traveling time is the sum of the time on each junction, which can be calculated by Equation. 6.

$$Ť_t = \text{Sum}\ (ţ_{i,j})\ \text{where i, j= 1…n} \tag{6}$$

TABLE IV. THEORETICAL CAPACITIES FOR SINGLE LANE

| Speed (km/h) | Headway | Traffic density (vehicle/km) | Traffic flow (vehicle/hour) |
|---|---|---|---|
| 8 | 17 | 103 | 518 |
| 16 | 22 | 80 | 800 |
| 24 | 28 | 63 | 941 |
| 32 | 36 | 49 | 976 |
| 40 | 44 | 40 | 1000 |
| 48 | 53 | 33 | 995 |
| 55 | 62 | 28 | 994 |
| 65 | 70 | 25 | 1006 |
| 72 | 79 | 22 | 1003 |

The flow chart of proposed work is shown in Fig. 6.

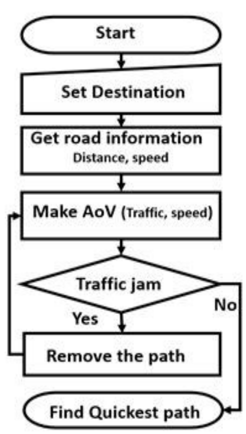


Fig. 6. Flow chart quickest path selection algorithm

## V. Experimental Results

The performance of suggested quickest path selection algorithm is evaluated by focusing on achieving the fastest path. The results have been compared with the traditional Ant Colony algorithm. or the experiment, we used a data set with arbitrary road information to create a typical road network and compare our proposed algorithm with the ACO algorithm. Fig. 7 shows the road network with distance and vehicle's current speed.

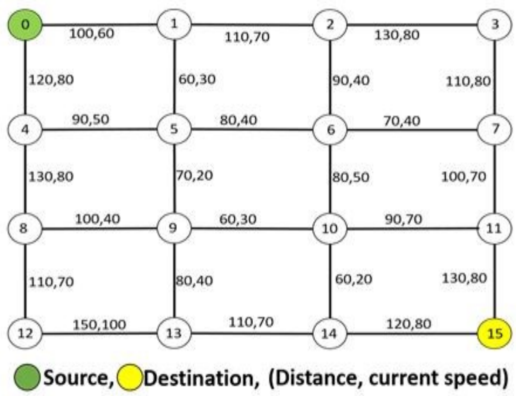


Fig. 7. Archetypal road network

Node 0 to 15 represents junctions. It is assumed that junction 0 is the origin and junction 15 is the destination. To evaluate the algorithm the different traffic situations are being observed. Traffic congestion is inversely proportional to the speed, therefore we observed both algorithms on different traffic ratios. For increasing traffic we reduced the vehicle's current speed at each road with same ratio. With different traffic volume we observed the behavior of both algorithms. Fig. 8 shows the path accomplished by ant colony algorithm while Fig. 9 shows the path selected by our proposed algorithm.

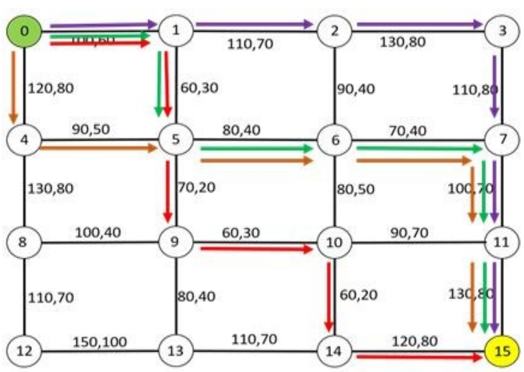


Fig. 8. Path selected by Ant Colony w.r.t traffic ratio

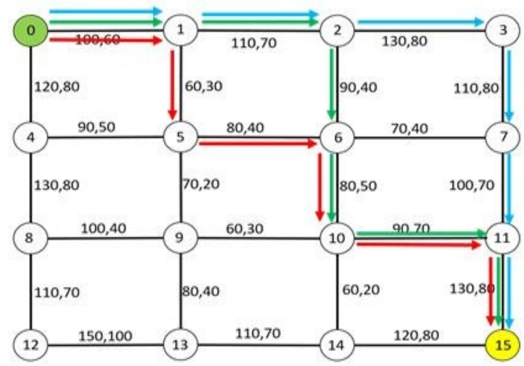


Fig. 9. Path selected by proposed algorithm w.r.t traffic ratio

The comparison of total distance travel by both algorithm is shown in Fig. 10 while total travel time is compared in Fig. 11.

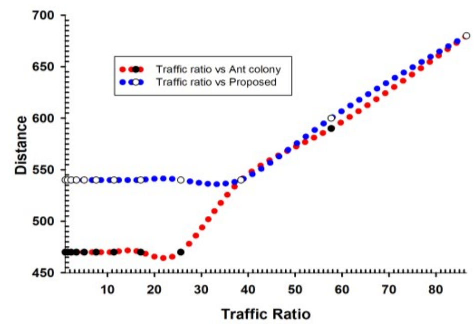


Fig. 10. Total distance travelled w.r.t traffic ratio

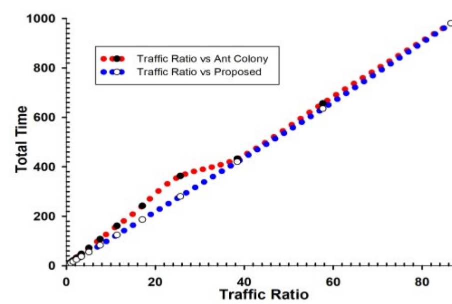


Fig. 11. Total time taken w.r.t traffic ratio

The experiment shows that proposed algorithm choose the path that has less traffic flow or in other words with less traffic volume even longer path but Ant colony algorithm choose the shortest path. On the other hand it is clearly shown that Ant colony takes more time compare to proposed algorithm in traveling. At the point where each road traffic volume reaches to the maximum density, the both algorithm choose the same path and spend same time on the road.

Another experiment has been made with random road traffic and speed to analyze the performance of the proposed algorithm. With random road traffic situations Ant colony algorithm found the path shown in Fig. 12 whereas the path selected by proposed algorithm is shown in Fig. 13

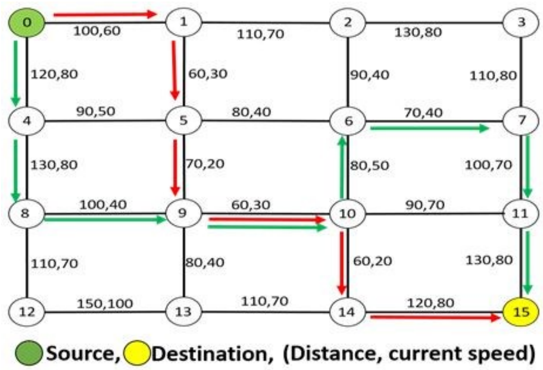


Fig. 12. Path followed by Ant colony in random road situation

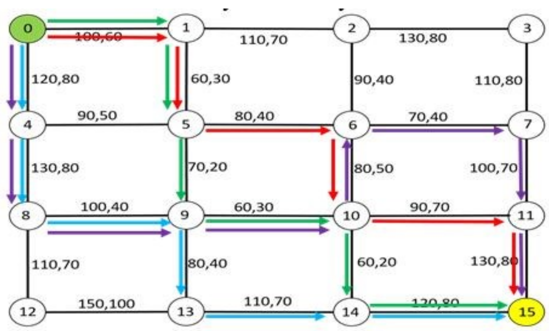

Fig. 13. Path followed by the proposed algorithm in random road situation

The total distance and time traveled by both algorithms are shown in Table 5.

TABLE V. DISTANCE AND TIME COMPARISON BETWEEN ANT COLONY AND PROPOSED ALGORITHM IN RANDOM TRAFFIC SITUATION

| Traffic range | Distance Ant colony | Time Ant colony | Distance proposed | Time Proposed |
|---|---|---|---|---|
| 1~31 | 470 | 68 | 660 | 51.50 |
| 11~41 | 470 | 130.17 | 470 | 130.17 |
| 21~51 | 470 | 243.17 | 520 | 230.67 |
| 31~61 | 470 | 285.83 | 470 | 285.83 |

## VI. CONCLUSION AND FUTURE WORK

The quickest path selection algorithm calculates the congestion on the road section and choose the path that has less traffic flow and reach to the destination in comparatively short time. If the traffic jam is not severe, the time and distance that the ant colony algorithm and proposed algorithm take to travel from origin to the destination is the same in terms of performance. But it is necessary to mention that the experiment is made on a small road network architype. The performance of the proposed algorithm is superior to other algorithms when the road conditions vary and the environment changes in real time. It is evident by the experiment that our algorithm choose the quickest path instead of selecting the shortest path. Experimental results show that the proposed algorithm can solve the urban problem caused by congestion by using the road more efficiently and shortening the time to the destination. For future study we will use the big data of vehicular transportation and road network around the world. By applying artificial intelligence, more efficient analysis of traffic situation and optimized path search to destination are left as future works.


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