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REVITALIZING URBAN MOBILITY: A COMPREHENSIVE ANALYSIS OF TRAFFIC FLOW AND SUSTAINABLE SOLUTIONS AT THE UN-SIGNALIZED TAXILA INTERSECTION

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Abstract- **In recent years, traffic congestion has become one of many cities' most significant financial and ecological concerns worldwide. It also costs citizens a substantial amount of time and fuel. Many experts believe that identifying traffic congestion characteristics is the first step in reducing traffic congestion. This study aimed to determine the extent of traffic congestion and fuel consumption at Taxila Chowk. The research's primary methodological tools were a traffic volume survey and peak hour volume study using Aimsun software. According to this study, auto-rickshaws, bicycles, motorcycles, and trucks were the most common modes of transportation. Traffic flow is particularly heavy in the morning, noon, and evening hours. It was revealed that the H.M.C. road is the most congestion-prone route compared to the other four routes. Also, the distinctive design of rickshaws and bus stands and the misplacement of fruit and vegetable markets play a considerable role in Congestion. The level of service of the four routes is almost intolerable, and the sole P.O.F. road that offered comparable better services to city commuters is an acceptable illustration. The study has also identified the amount of fuel consumption on each route, focused on the environmental impact of Congestion due to emissions of green gasses, and provided feasible solutions in the form of alternatives.**

keywords: **Traffic Congestion, Traffic management, Simulation, Fuel Consumption, Aimsun Software, Smart Technology, Internet of Things (IoT), Data Analytics.**

I. INTRODUCTION

Road transportation has a significant role in economic activity and prosperity. It also has a considerable impact on individual well-being and regional development. Cities, especially those in emerging nations, have experienced a dramatic rise in transportation-related issues such as pollution, traffic congestion, accidents, and environmental destruction. However, there's more of a problem with traffic congestion now[1]. Along with having an impact on people's everyday lives, it also hinders the advancement of civilization[2-4]. Congestion has resulted because of several factors: the rapid increase in a population known as urbanization[5], the increased purchasing power of ordinary men, relative price reductions, and the increased availability of used automobiles[6]. It is worth noting that traffic congestion is not limited to automobiles; pedestrian (non-automobile) traffic congestion has been extensively researched in order to create evacuation tactics and crowd control methods; it has an impact on everyone in developed countries as well as a large number of people in developing nations[7,8]. Road construction, enhanced alternative modes, price adjustments, and smart growth land use rules are employed in the evaluation of four congestion-reduction techniques. The results show that highway expansion typically yields less overall value than other congestion-reduction approaches. A thorough examination can help to develop more efficient and fair congestion solutions[9]. Another study was designed to ascertain the Karachi, Pakistan traffic congestion with a conventional approach, like the number of traffic parameters collected through field surveys[10]. Intelligent transportation systems, traffic pattern monitoring, and signal timing adjustments can all improve traffic flow in intelligent cities. Their primary objective is to prevent jamming up the system and to adopt green technologies (e.g., to reduce the use of fuel, gas, and energy) [11]. Congestion has so developed into a complicated and well-established issue. The topic gets far more complex when considering locations, causes, consequences, solutions, and implications. The difficulties and solutions vary depending on the route taken[12-14]. Besides traffic congestion, high fuel consumption is a major problem on congested routes, as road users impose extra travel time and vehicle operating costs due to traffic congestion. Robertson et al. adjusted signal timings to reduce fuel usage with TRANSYT 8. The fuel usage was calculated using a linear relationship with traffic performance measures (delay, stops, and average speed) (delay, stops, and average speed). Another fuel study has been reported by optimizing signal timings using CMEM(Comprehensive Modal Emissions Model) emissions calculations for a population of autos with individual driving behaviors modeled in VISSIM. Optimization was used to minimize fuel consumption and CO_2 emissions [15].

According to several sources, gasoline and diesel cars are bad for the environment, contribute to global warming, and increase air pollution levels in megacities above what is allowed.[16,17].Growth in transportation options is also accompanied by an increase in the amount of traffic on urban roads, delays in service, fuel consumption, and rapid component wear. The urban populace is exposed to the harmful gases that automobiles produce and the small particles that tires and brake components emit[18,19]. A lot of energy is wasted during traffic congestion, which causes a lot of carbon monoxide (CO) to be released from car engines. As carbon monoxide burns in the presence of oxygen (O_2), carbon dioxide is created (CO_2). The amount of CO_2 (Carbon dioxide) emissions is significantly impacted by traffic congestion and variations in vehicle speeds[20]. CO_2 emissions double per mile when the speed drops from 30 mph to 12.5 mph or from 12.5 mph to 5 mph[21]. Over the past few decades, environmental pressure and energy scarcities have increased, and traditional road travel is now generating increasingly serious issues owing to carbon emissions and energy usage. One of the many different forms of environmental repercussions, greenhouse gas (GHG) emissions, is regarded to be the primary cause of climate change. According to the Environmental Protection Agency (E.P.A.), one of the significant sources of GHG emissions is the transportation sector; in many locations, vehicle emissions are now a substantial source of air pollutants such as nitrogen oxides (NO_x), carbon monoxide (C.O.), carbon dioxide (CO_2), volatile organic compounds (V.O.C.s) or hydrocarbons (H.C.s), and particle matter (PM) [22,23].

Traffic congestion mitigation can be achieved through the implementation of viable alternatives. The validation of these alternatives can be effectively conducted using Aimsun software, an acronym for Advance Interactive Microscopic Simulator for Urban and Non-Urban Networks. Aimsun is a sophisticated Transport Simulation System (T.S.S.) designed explicitly as a microscopic traffic simulator capable of accommodating diverse urban and non-urban networks, including freeways, motorways, ring roads, and arterials.

This cutting-edge software has been meticulously crafted and developed to serve as a comprehensive traffic analysis tool[24]. Its primary objective is to aid traffic engineers in meticulously designing and evaluating transportation projects and traffic

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systems. The versatility of Aimsun allows it to model and simulate intricate traffic scenarios with a high level of precision and detail, making it an indispensable asset in the realm of transportation planning and optimization.

Aimsun operates on a microscopic level, meaning it takes into account the individual dynamics of vehicles within the traffic system. This includes factors such as driver behavior, traffic signal timings, road geometry, and the nuanced interactions between vehicles. The microscopic simulation capability sets Aimsun apart, providing a realistic representation of how changes to the transportation infrastructure may influence traffic flow and congestion levels.

One of the distinctive features of Aimsun is its applicability to a wide range of network configurations. The software can adapt to various scenarios, whether dealing with bustling urban networks or extensive freeway systems. This adaptability empowers traffic engineers to assess and optimize transportation projects across different contexts, ensuring the effectiveness of proposed solutions[25]. The software's capacity to validate alternatives is crucial in decision-making. Engineers can input different scenarios into Aimsun, allowing them to gauge the impact of proposed changes before their actual implementation. This iterative testing and validation process not only enhances the precision of transportation planning but also contributes significantly to the reduction of traffic congestion. In essence, Aimsun serves as an indispensable tool for traffic engineers, providing them with a powerful means to design, analyze, and optimize transportation projects. By offering a detailed and realistic simulation of traffic dynamics, Aimsun facilitates informed decision-making in the pursuit of efficient and congestion-free transportation systems. Its role extends beyond a mere simulator; it stands as a key asset in the pursuit of sustainable and effective urban mobility solutions[26,27]. The AIMSUN program is one of the world's top micro-simulators, allowing you to replicate a wide range of traffic components, methods, and approaches. The software is a full-featured collection of tools to analyze traffic flows and traffic, which may be used for transportation planning, comprehensive modeling, and research needs and conditions of activity. The software has an integrated platform that may be used for static and dynamic modeling[28,29]. The program may cope with various transportation networks, including urban networks, highways, ring roads, arteries, and combinations [30,31].

A long-standing problem that has gone unsolved is traffic congestion. The management of traffic congestion in Taxila, Pakistan, is this research's main area of interest. In particular, it offers a solution for the congested traffic at the Taxila intersection. The study considers several traffic-related solutions while acknowledging the unavoidable Congestion in urban settings. Using digital assessments of the current traffic condition, the research suggests a revolutionary control strategy for removing existing Congestion and reducing Congestion. Additionally, this study suggests a unique control mechanism for fuel consumption after traffic congestion has been lessened. Also, the Impact of Congestion on the environment (Carbon emissions mainly) has been taken into consideration for the Taxila intersection, as Air pollution is a threat to the lives of people living in big cities of Pakistan. Taxila's air has reached a high level of pollution.

II. STUDY AREA

The study area is located in one of Pakistan's economic core cities, Taxila, and is critical to providing service to the industrial sector. It is strategically located on the National Highway, N-5, Pakistan's longest National Highway, from Karachi to Torkham. Our research area encompasses a section of the N5 national highway from Barrier 5 to the Royal Son Hotel. Poor design of Bus and Rikshawa stands, unlicensed parking, and vendor marketing reduce the roadway's actual width.

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All of this adds up to a busy junction and results in Congestion, high fuel consumption, and emissions. Heavy traffic from the Hattar industrial complex and other cement mills on that route exacerbates the situation. The most noticeable sign of Congestion is increased travel time, particularly during peak hours.This area is located 2 kilometers away on Rawalpindi Road. The location of the investigated area is depicted in Fig. 1. It demonstrated that there are numerous conflict points for traffic moving in separate directions. There are a total of five routes symbolized by A(Westbound toward Taxila), B(Eastbound Toward Rawalpindi), C(North Hattar Haripur), D (P.O.F. Toward Taxila), and E(Tatta Khaleel Road).

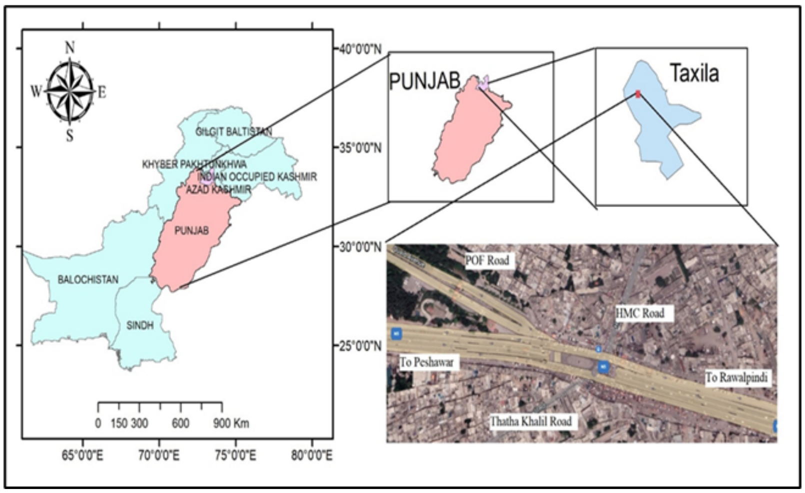

Figure 1: Road Network at Taxila Intersection (33° 44’14.5"N, 72° 47’54.4"E) [31].

III. METHODOLOGY

The study approaches acquired valuable data about Taxila traffic congestion. Different criteria and alternatives from the literature were selected. The visits took place on several days, from 7 am to 7 pm, for 12 hours. These findings sought to quantify the traffic volume going through these sites. Talley sheets were eventually used to count the number of cars passing through each junction lane individually. Then traffic data was analyzed, and P.C.U.(Passenger car unit) and P.H.F (Peak hour factor) were determined. Real-time information and traffic flow during peak hours were used to enter the results into the traffic software AIMSUN. Finally, the data were compared, and an appropriate alternative was chosen. Control, measurement, and management of traffic flow were investigated using formal mathematical methodologies. The average speed for each route obtained was used for calculating L.O.S. and Fuel consumption, and then the emission of Greenhouse CO_2 gasses was estimated. Fig.2 Shows the methodology used.

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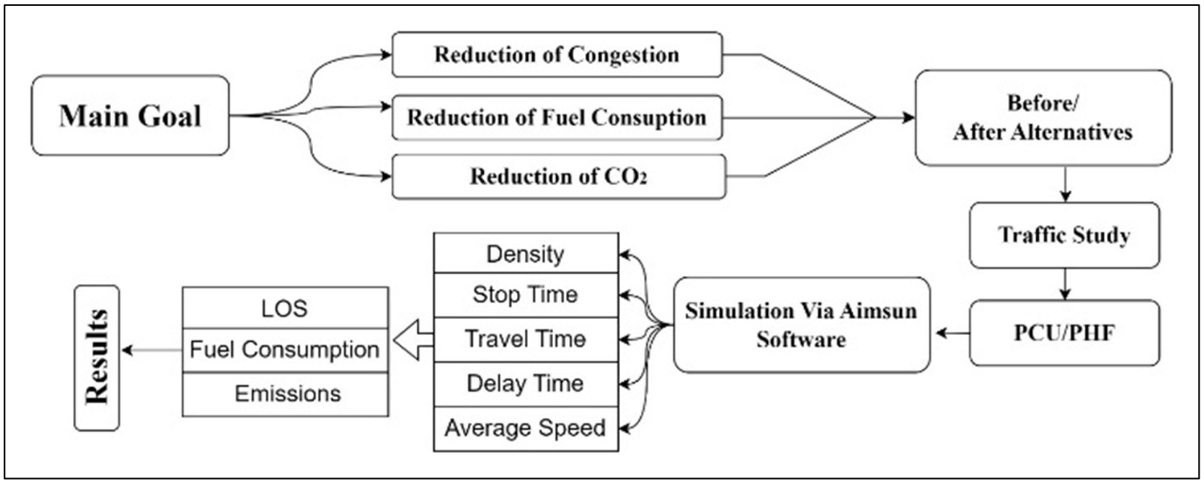

Figure 2: Methodology used in the whole study.

A. *Traffic Count Survey*

The term "manual counting" refers to a traffic counting approach categorized as "manual." Vehicle counts at intersections, classification data, or video records might all be employed. All occurrences of traffic counting are estimates of average daily traffic and daily traffic per year[26,27]. Traffic counting has occurred on all existing routes, i.e., vehicle flow was counted for different times and on other days for routes A, B, C, D, E, and F from 07:00 Am to 07:00 pm on each 15-minute interval in the tally sheet. Vehicles were computed separately based on their kind, such as bicycles, passenger vehicles, single-axle trucks, and two-axle trucks[28]. After counting, further analysis was carried out on Microsoft Excel. Data were analyzed to determine the Traffic volume, Peak hour, Peak hour factor (P.H.F.), and Passenger car unit (P.C.U.) for all routes, is shown in details in section V.

B. *Passenger Car Equivalent (PCE)*

The Passenger Car Equivalent (PCE) or Passenger Car Unit (P.C.U.) value is critical for any vehicle traffic flow analysis. Passenger car equivalents (PCE) are elements that are used to transform a traffic stream made up of various vehicle kinds into an equivalent traffic stream made up entirely of passenger vehicles[29,30]. The values of P.C.E. for various vehicles were listed in the H.C.M. (Highway Capacity Manual), as indicated in Table I.

C. *level of service (L.O.S.)*

Usually, traffic is classified qualitatively using a six-letter A-F level of service (L.O.S.) scale outlined in the Highway Capacity Manual, L.O.S. for signalized and unsignalized junctions as a function of average vehicle control delay[33-35]. The level of service (L.O.S.) is a flow quality measurement[36]. The DPWH Highway Planning Manual and the U.S. Highway Capacity Manual(2000) standards addressing the level of service (L.O.S.) of arterial routes were used to categorize the various traffic situations. Table II shows the Intersection of these two standards, together with the traffic volume and the average speed [37].

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TABLE I
Passenger car equivalent (PCE) values[32]

S.No	**Vehicle Type**	**P.C.E**
1	Animal Driven Cart	4
2	Motor Cycle/Rickshaw	0.5
3	Bicycle	0.2
4	Passenger Car/ Jeep	1
5	Large bus	3.5
6	Hiace/Coaster	3
7	2-Axle Truck	4
8	3-Axle Truck	5
9	Long Vehicle	6
10	Tractor Trolly	4

TABLE II
Level of Service (L.O.S.) with Average Speed and Traffic

L.O.S.	**Traffic Condition**	**Average Speed(KPH)**
A	Free Flow	> 67.2
B	Free Flow	> 54.4 to 67.2
C	Moderate	> 43.2 to 54.4
D	Moderate/ Heavy	> 33.6 to 43.2
E	Heavy Traffic	> 25.6 to 33.6
F	Forced Flow / Stop and Go	≤ 25.6

IV. ANALYSIS OF RESULTS

Traffic counting has occurred on all existing routes, i.e., vehicle flow was counted for different times and on different days for routes A, B, C, D, and E. Fig.3 demonstrates that there is heavy traffic on route C in case of 12 hours traffic flow and during peak hours.

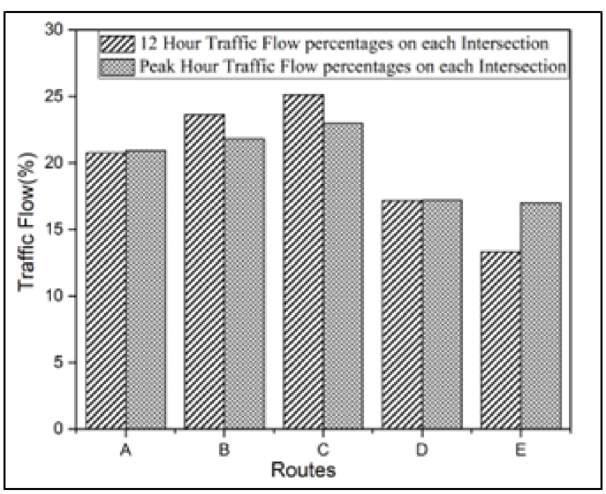

Figure 3: Twelve hour Peak Hour Traffic Flow percentages at each Intersection.

Fig. 4 demonstrates the percentage of different kinds of vehicles observed for 12 hours with 15-minute intervals on each intersection route; the maximum flow of cars was observed on route D. Motorcycles on route E, and heavy trucks on route C (North Hattar Haripur).

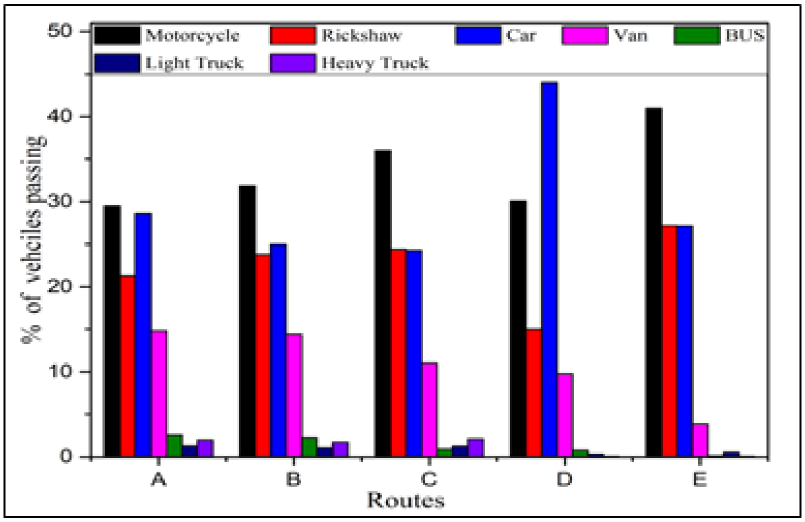

Figure 4: Percentages of different types of vehicles on all routes.

Traffic volume for each route where vehicles were passing with an interval of 15 minutes for 12 hours was compared, as shown in Fig. 5.

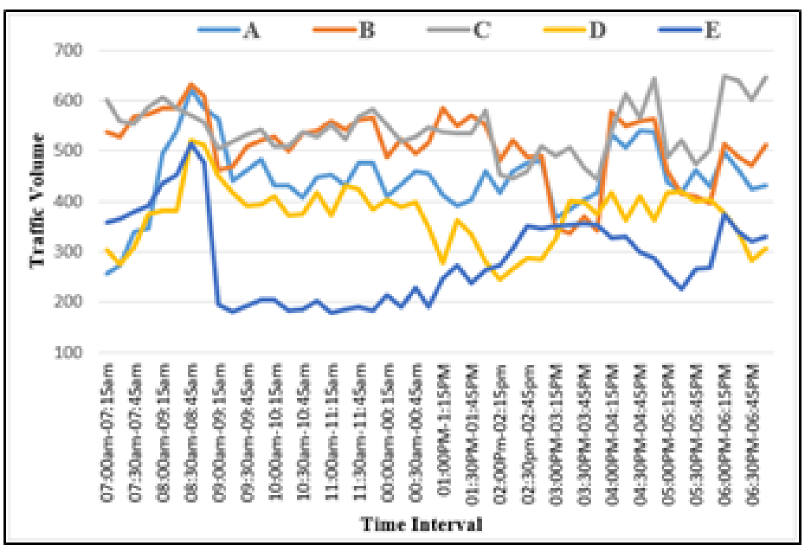

Figure 5: Percentages of Different Types of Vehicles on all Routes.

Further analyses were conducted on Microsoft Excel to determine the traffic volume, Peak hour, Peak hour factor (P.H.F.), and Passenger car unit (P.C.U.) for all routes, as shown in the table.it is shown that for four routes, peak hour was observed in the morning from 8:00 Am to 9 Am, which is due to the school and office timings, while on route "C," the peak hour is from 6:00 pm to 7:00 pm which is due to the heavy vehicle on Hattar Road from industries zone. For four routes (A, B, D, E), the peak hour was observed in the morning from 8:00 Am to 9 Am due to school and office timings, while on route "C," it was 6:00 pm to 7:00 pm which is due to the heavy vehicle flow on Hattar Road from industries zone.

A. Selection of Feasible Alternative based on AIMSUN

The research area has been chosen to include three alternatives listed below.

- Signalized intersection (A1) Intersections may be signalized to solve difficulties with traffic safety, efficiency, or operation or to increase the number of places pedestrians and bicycles may cross safely[37].
- Parking Areas (A2) Parking is a crucial part of the transportation system. Every location requires parking for automobiles. Parking convenience influences how easily locations may be reached, which impacts accessibility in general [38].
- Flyover (A3) To improve traffic flow and assist in decongesting it at a busy intersection.

Analysis of the peak hour traffic data on Aimsun software was conducted to know each route's current condition and L.O.S. The indicators for this study, determined from Aimsun software, were travel time, density, average speed, and delay time. The Aimsun software data for the current road condition is shown in Table III. Then, based on average speed, L.O.S. was determined for each route. The table of L.O.S. against average speed is also shown in Table III, from which we find the L.O.S. for each route. Here, Aimsun Software was employed for two scenarios, i.e., before alternatives and after alternatives.

B. Simulation Before Alternatives

When Aimsun software was employed without an alternative, it showed that the L.O.S. of routes A, B, and C is E, so the Average speed is low, and the Density and Delay time were high, which justifies that on this route, there is heavy traffic and very minimum gaps between the vehicles, Maneuverability is possible only under constraint for another vehicle, road user is frustrated, and the level of comfort is significantly less.

Path D shows L.O.S. C while Path E shows L.O.S. D. It implies that the presence of other cars impacts drivers. The choice of speed is impacted, and maneuvering requires attention to detail. As the driver's perception of being trapped between other vehicles grows, the level of comfort rapidly declines at this level a low degree of comfort for the driver since it is necessary to prevent collisions with other cars continually. Possible L.O.S. is A, B, C only as shown in Table 3 below, therefore, the L.O.S. with indicators of Aimsun software too is analyzed, the worst traffic condition is on route "C," and "B" the traffic on route "C" is due to the heavy vehicles which come from cement factories, glass industries, and other heavy industries and on route "B" is due to fruit markets and unlicensed parking area which minimize the roadway width which affects the vehicle moving on route "B" mainly as shown in Fig. 6.

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TABLE III
Level of Service (L.O.S.) with Average Speed and Traffic

Alternatives	**Route**	**Delay Time** (Sec)	**Stops**	**Density** (Veh/Km)	**Total Travel** (veh hr)	**Average speed** (Km/Hr)	**L.O.S.**	**Fuel Consumption** (Liters)
Before Alternatives	A	179	12.11	112	1435.131	31.34	E	245.59
	B	183	14.36	121	1495.989	28.7	E	270.49
	C	203	18.7	134	1574.235	25.91	E	300.76
	D	156	8.6	86	1179.279	47.22	C	133.11
	E	171	9.2	101	1166.238	35.11	D	183.87
Flyover	A	155	8.22	93	1435.131	45.2	C	172.01
	B	174	12.7	113	1495.989	31.76	E	253.55
	C	176	11.3	117	1574.235	37.7	D	232.09
	D	142	5.1	69	1179.279	55.03	B	98.98
	E	163	7.8	87	1166.238	36.4	D	178.29
Parking Area	A	165	10.7	101	1435.131	39.4	D	202.82
	B	148	7.9	92	1495.989	46.9	C	169.76
	C	169	16.3	111	1574.235	29.31	E	280.93
	D	148	7.6	74	1179.279	52.1	C	111.82
	E	136	5.8	78	1166.238	54.9	B	98.49
Signalized Intersection	A	161	9.23	97	1435.131	44.02	C	178.29
	B	159	11.7	103	1495.989	37.5	D	221.80
	C	164	14.3	111	1574.235	34.12	D	252.93
	D	149	6.9	79	1179.279	49.8	C	121.82
	E	152	8.13	89	1166.238	45.91	C	137.30

Figure 6: Worst Congestion situation at Taxila Chowk due to irregular parking and vendor marketing

C. Simulation After Alternatives

Possible alternatives to solving the critical problems were employed through Aimsun software. Each alternative and its impacts were studied in succession. The first alternative that was applied is a flyover, which will join the three routes Peshawar to Rawalpindi(A), P.O.F. (D), and H.M.C. road(C). It has resulted in a good reduction of Congestion of routes

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C and A, shown in Table III and Fig. 7(c), as their L.O.S. has decreased. Additionally, the average speed has increased, and delay time has also been reduced.

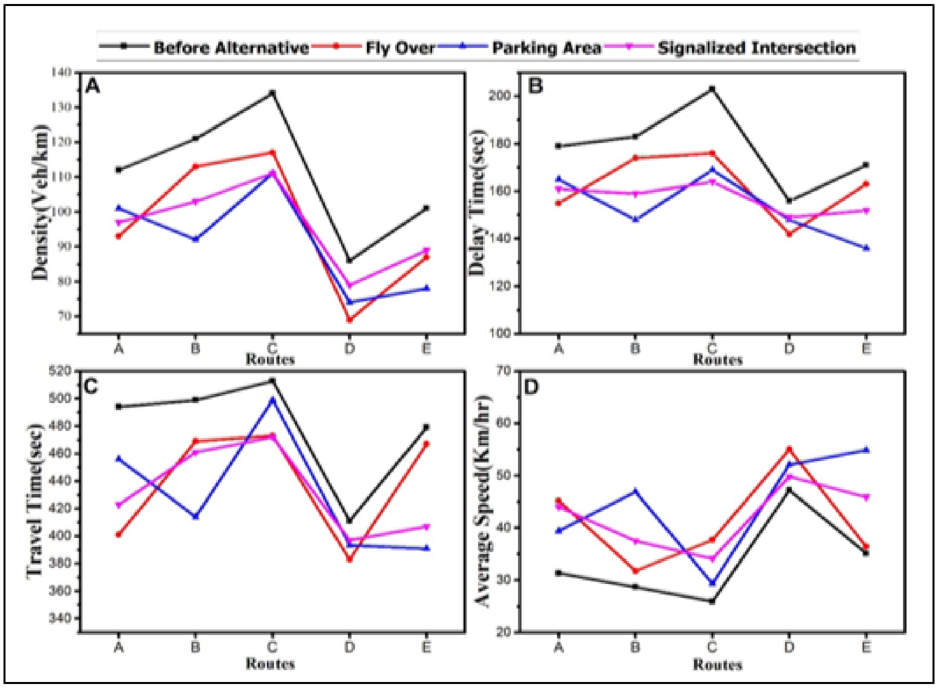

Figure 7: Images result from simulation on Aimsun software a) Before Alternatives b) Fly over c) Parking Area d) Signalized Intersection

For the reduction of congestion of routes "B" and "E," some space for a Parking area was allocated at Royalson Hotel(A few meters away from Taxila Chowk), which is shown in Fig. 7(c), it has awesomely improved the traffic condition on "B" and "E," then 3rd important alternative was employed in software that is to make the Intersection signalized which is shown in Fig. 7(d) and signal on Intersection shows a significant result for all the routes. Fig. 7 (a,b,c, and d) resulted from Aimsun software. Overall, the alternatives provided have significantly reduced the L.O.S., Density, and Delay Time, while Average speed has Increased on all routes, as shown in Table 3.

V. FUEL CONSUMPTION

The formula used for determining Fuel consumption by VISSIM, TRANSYT-7F, and SYNCHRO reads as follows [16].

$$F = total\, travel \times k_1 + Total\, delay \times k_2 + stop \times k_3 \tag{1}$$

Where, k_1 = 0.075283- 0.0015892 Speed+0.000015066 speed2, k_2= 0.7329, k_3 = 0.0000061411 speed2, F = fuel consumed (gal), Speed = Average speed (mph), Total travel = vehicle miles traveled (veh mi), Total delay = total signal delay (hr), stops = total stops. It was observed that providing alternatives reduces fuel consumption compared with the initial or before alternatives, as shown in Fig. 8. Delay time, density, average speed, and several stops on each route are the critical inputs obtained from Simulation through Aimsun software and have been used as objective functions for Eq.1 to calculate fuel consumption. The main issue is how an objective function reports system performance when there is considerable network delay. Providing alternatives like Flyovers, Parking areas, and signalized intersections impacts the delay time, average speed, and total travel. In General, Delay time decreases, and average speed increases. As a result, fuel is consumed less.

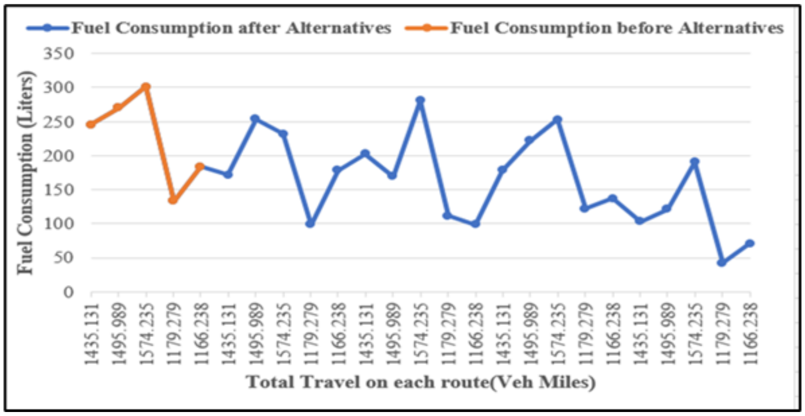

Figure 8: Fuel consumption before and after alternatives

Fig. 8 shows that initial fuel consumption was much more than the fuel consumption after the alternatives; the maximum amount of fuel consumption was observed on Route C as the L.O.S. is E because the average traffic here consists of heavy traffic. Also, the presence of the most stops on this route is a major cause of maximum fuel consumption; after providing an over on route C, as shown in Fig. 7, The fuel consumption was reduced by 22.83%; similarly, by providing a parking area and signalized Intersection, it was reduced 6.59% and 15.90% respectively as shown in Table IV, So with getting better of L.O.S. the fuel consumption reduces correspondingly, also by providing Parking Area and Signalized intersection fuel consumption has been reduced for the respective routes as shown in Table IV.

TABLE IV
Percentage of fuel consumption reduce after alternatives.

Routes	Fly Over	Parking Area	Signalized Intersection
A	29.96%	17.42%	27.40%
B	6.26%	37.24%	18.00%
C	22.83%	6.59%	15.90%
D	25.64%	15.99%	8.48%
E	3.04%	46.43%	25.33%

VI. EMISSIONS OF GASSES DUE TO TRAFFIC CONGESTION

Before the alternatives were applied, it was found that the Taxila Intersection was too congested that the average speed on routes A, B, C, D, and E were 31.34 km/hr, 28.7 km/hr, 25.91km/hr, 47.22km/hr and 35.11km/hr respectively which is too low result in the release of greenhouse gasses NOx, Sox, particulate matters and especially CO2 in huge amount, which

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adversely impacts the environment and plays a major role in Global warming and acid rains. Fig. 9 shows the emissions curve over the road speed for gasoline vehicles. A minimum speed of 60 to 70 km/h is required for the emissions factor, and emissions are increased with a lower speed. Due to the nonlinearity of the emissions component, traffic congestion must be taken into account while estimating emissions. Just using the average speed would result in an estimation of CO2 emissions.[38] Before alternatives, the average speed was less, so CO2 emissions were high; by applying alternatives, the average speed has been increased, and emissions will be low, as shown in the figure.

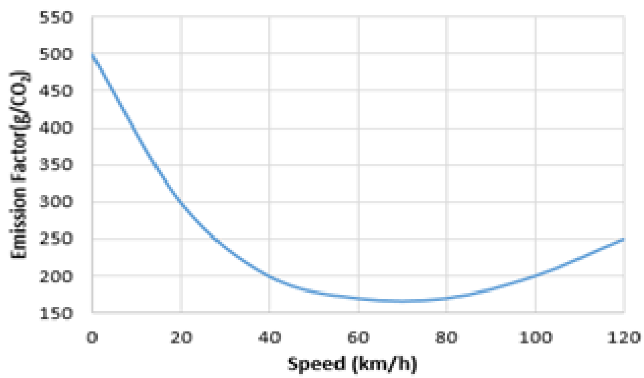

Figure 9: CO2 emissions factor over the average travel speed by gasoline vehicles [38]

VII. CONCLUSION

It was found that H.M.C road was the most congested route of all other four routes, and the level of service of all intersections was not acceptable except for P.O.F road, so providing alternatives on the Intersection which provides a comparatively better level of service to the travelers of the city. It was observed that all alternatives show positive results when applied one by one, therefore, all alternatives (Flyover, Allocate Parking Area, and signal on Intersection) should be provided simultaneously. L.O.S. of all the routes are accepted and give us smooth Intersection flow. In addition, fuel consumption and emissions were reduced, leading to low cost and low time for traveling and providing us with sustainable means of transportation.

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CONFLICTS OF INTEREST

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