

Quantifying Traffic Congestion by Studying Traffic Flow Characteristics in Wolaita Sodo Town, Ethiopia

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Abstract

Road traffic congestion is one of the main problems in developing countries. Congestion mainly occurs at peak time when the road way capacity fails to function the road way activities. Congestion result in frustration that deals with many unknown accidents, weak road way safety, decreases the aesthetic value, Increases travel time because of a lot of delays, results in air pollution and noise pollution, carbon dioxide (CO₂) emissions and fuel use and energy loss because cars cannot run efficiently. Even though the problem being recognized by all road users and transport professionals, there is only insignificant attempt for solution and relative research done on the extent of the traffic congestion in wolaita sodo town. This research work mainly focuses on traffic flow characteristics such as Average Speed, density and Traffic Volume. The inter relation of these parameters have great impact to quantify road traffic congestion. The data collected from the traffic volume is used to calculate flow, Capacity and directional level of service (LOS) for selected stretch of road segment. Speed is an important congestion measurement which is related to travel time and mainly influenced by the density. The speed and traffic volume data was collected manually on mid-block for solid 12 hours in selected peak days of the week. In this paper the average speed, travel time, flow and density are calculated and the relationship is studied with road capacity. The study gives recommendations for the improvements of LOS for the proper operational traffic on the road.

Keywords: Traffic volume, flow, Average speed, density, Travel time, Peak hour factor, Saturation flow rate, Design Hourly Volume, Headway, capacity and level of service

1. Introduction

The fast economic, social, educational, recreational activities and political development will increase urbanization. This attracts a massive numbers of trips to urban areas. The traffic in urban areas is highly congested and heterogeneous in nature. The traffic in urban areas is facing lot of problems in every day and encounters delays in most of the peak periods. Urban road network congestion can be occurred due to road users and size of the road network. Double parking or parking on roadway, pedestrian movement, motorized vehicle, non-motorized vehicle and roadside markets are the main road congestion factors.

1.1 Background of the Study Area

With the development of economy and technology, many Ethiopian cities and sub cities have experienced rapid growth of private vehicles. Wolaita sodo is one of the typical cities, which is also in the process of urbanization especially in the latest decades. According to the data from town finance Economic Development office recently, the total number of the town's residents exceeds 120,000. However the office says that the number of population is increasing in high level due to continues rural-urban migration to this end, as Wolaita Sodo town Administration Office and the town is located in the strategic place for the southern Ethiopia. It has seven outlets which connects the north, south, east and west areas. These are Sodo-Hossana-Addis Ababa, Sodo-Arba minch-Jinka, Sodo-Waka-Jima, Sodo Gofa/Sawula, Sodo- Bedessa Moroch –Hawassa, Sodo- Boditi shashamane-Addis Ababa and sodo-Humbo –Dimtu-Dilla. These outlets makes the town one of the commercial and recreation centers for the surrounding zones and also for the region. Furthermore it serves as an education center for the surrounding areas. The majority of the people in the town are leading their livelihood by undertaking small & medium trade. The annual growth rate of the town's population is 5.4%. With the process of urbanization, the size of urban areas of Wolaita sodo is growing and the construction areas are expanding to the nearest road routes.

1.2 Statement of the problem

In Developing countries like Ethiopia, transportation system management is poor and is one of the major cause for the congestion on the roads. Currently urban development is increasing day to day in Ethiopia. The number of vehicles is also increasing in fast. Social, economic and also political developments are rising in cities, sub cities and towns. Wolaita sodo town as other developing towns and cities in Ethiopia, is facing weakness in road transportation system management. Having a several road routes, the traffic flow is mainly concentrated in one route. Housing development and commercial activities are increasing. This resulted in road congestion by Heterogeneous Mixed Traffic through. Traffic congestion has now become the major threat in the town economic growth by restraining the commuter mobility especially at peak hours. Even though the problem being recognized by all road users and transport professionals, there is only insignificant attempt for the solution and relative research done on the extent of the traffic congestion in wolaita sodo town.

1.3 Specific Objectives

- To determine the traffic flow characteristics in selected road route
- To collect the roadway inventories or complete list of items such as goods in stock or the contents of a building and roadway width.
- To forward possible solution for roadway congestion and forward recommendation

1.4 Scope of the study

This research study is limited to Wolaita Sodo town which is located in SNNPR, Ethiopia. The town is located 390 KM of south, 167 KM of south west of Addis Ababa and Hawassa respectively. Wolaita sodo like many other Ethiopia's towns, has been experiencing fast economic development and fast process of urbanization. Many urban transport problems are emerged at this time. As per 2015 central statistical agency of Ethiopia, the population census results and latest official projection of Wolaita Sodo town is 145,100. In addition there are a huge floating population from nearby localities for commercial, educational and recreation purpose. Among the several road routes the most congested one is as shown in the fig 1 below which extends from wolaita Sodo agricultural college to oil Libya.



Figure 1: location of study road network on Wolaita Sodo town (<https://www.google.com.et/maps>)

2. Literature Review

2.1 Definition of congestion

Congestion is a situation in which demand for road space exceeds supply. Congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches capacity (Chakrabarty & Gupta, 2015). Congestion is the state of traffic flow on a transportation facility characterized by high densities and low speeds (Weisbrod, et al., 2001).

2.2 Causes and Effects of Congestion

The general and main cause of congestion can be road width, supply and demand, double parking or parking on roadway, pedestrian movement, motorized vehicle, non-motorized vehicle and roadside markets. Kwon, et al. (2006) divided causes of congestion into several elements, such as collision, special events, lane closures, weather, congestion that can be eliminated by ideal ramp metering and congestion caused by demand that exceeds the maximum sustainable flow. As Skimson (2012), Congestion result in social/psychological impacts such as increased anxiety, stress and road rage.

2.3 Congestion Measures

Many more researchers and professionals used various thresholds to measure congestion. Skabardonis, et al., (2003) measured the total, recurrent and non-recurrent delays and defined congestion as vehicles traveling at a speed below 60 mph on urban freeways. Cottrell, (1993) measured a threshold value for congestion of a volume-to-capacity ratio of 1.0 for freeways by using data from the Highway Performance Monitoring System. Polus, (1993) conducted the Minute Mile of Congestion (MMC), which estimated the amount and duration of congestion. The threshold above which congestion occurred was 30% occupancy of a detector.

The present study is conducted to quantify the congestion by analyzing traffic flow characteristics.

3. Research Methodology

For this research work from the road networks in Wolaita Sodo town, the most congested route which is the almost 3.3 Km road (Oil Libya to Wolaita Sodo agricultural college) has been selected. The Directional Traffic Volume per 15 min of interval and speed data collection was done by researcher at peak days for solid 12 hours. In Wolaita Sodo town, the great market days are Tuesday and Saturday. The road network is highly occupied in all the week days. The traffic flow is very high throughout the whole day in these peak days and the road way is occupied by mixed traffic for the entire day. The data for this study was collected manually. The data was collected at four roadway segments along same road corridor in two directions. The traffic volume and speed data was collected at every 15 minutes consecutive intervals from morning to evening. The effective road width/and the actual width of road/ measurement was taken at each

segment. The saturation flow rate was determined by Webster’s method. The entire selected location is divided into five road segments or mid blocks. Segment 1 is agricultural college, Segment 2 is kihna academy, Segment 3 is Bus station intersection, Segment 4 is 21 Mazoria and Segment 5 is taken as Oil Libya. The study location is a two lane two way road without any median.

4. Data collection and Analysis

The data and its accuracy is a main source for the analysis and problem solution. The traffic volume and speed data, Headways is collected at the selected locations in Wolaita Sodo town covering both morning, afternoon and evening peak and non peak hours. The data is collected on Tuesday and Saturday in both directions of the selected location (Agricultural College to Oil Libya Road Segment). The data collected is later analyzed in the following tables.

Table 1: Directional Hourly traffic volume (Flow) for Mid-Blocks on Tuesday

Time	Segment 1 to 2		Segment 2 to 3		Segment 3 to 4		Segment 4 to 5	
	1 to 2	2 to 1	2 to 3	3 to 2	3 to 4	4 to 3	4 to 5	5 to 4
7:00-8:00 AM	620	584	899	843	661	780	646	876
8:00-9:00 AM	1122	997	1465	1586	1491	1292	1115	1365
9:00-10:00 AM	976	998	1104	1178	1354	1076	1091	1052
10:00-11:00 AM	908	900	1241	1251	1029	1135	1708	1729
11:00 -12:00 AM	1309	1151	2024	2385	1305	2146	2101	1913
12:00-1:00 PM	1158	1260	2077	1518	1456	1755	2091	1827
1:00-2:00 PM	983	1215	1285	1365	1424	1348	1314	1409
2:00-3:00 PM	969	1018	1046	1019	1220	1114	1129	1139
3:00-4:00 PM	842	1000	820	819	1031	1052	994	1077
4:00 -5:00 PM	1129	1094	1211	1157	1342	1341	1205	1314

Table-2: Time Headways (seconds/vehicles) at Mid-Blocks on Tuesday

Time	Segment 1-2	Segment 2-3	Segment 3-4	Segment 4-5
7:00-8:00 AM	2.990	2.067	2.498	2.365
8:00-9:00 AM	1.699	1.180	1.294	1.452
9:00-10:00 AM	1.824	1.578	1.481	1.680
10:00-11:00 AM	1.991	1.445	1.664	1.047
11:00 -12:00 AM	1.463	0.817	1.043	0.897
12:00-1:00 PM	1.489	1.001	1.121	0.919
1:00-2:00 PM	1.638	1.358	1.299	1.322
2:00-3:00 PM	1.812	1.743	1.542	1.587
3:00-4:00 PM	1.954	2.196	1.728	1.738
4:00 -5:00 PM	1.619	1.520	1.342	1.429
5:00 -6:00 PM	1.035	0.898	0.901	1.235
6:00 -7:00 PM	1.835	0.936	1.368	1.484

The density, Capacity, Peak Hour Factor, Flow ratio, V/C ratio and Level of Service are calculated and are tabulated as below.

Table-3: Average Speed, Average travel time, Flow and Density at congested segments for peak hours. (Agricultural College to Oil Libya road segment) on Tuesday

Road Segment	Time	Distance (m)	Average speed (Km/hr.)	Travel time (Sec/Km)	Flow (Vehicle/hr.)	Density (flow*travel time(Veh/km))
1 to 2	Morning	30	33.3	108.11	1122	33.69
	Afternoon	30	31.5	114.29	1309	41.55
	Evening	30	30.2	119.15	1855	61.39
2 to 3	Morning	30	30.9	116.67	1465	47.47
	Afternoon	30	15.3	234.80	2024	132.0
	Evening	30	15.3	235.29	2533	165.55
3 to 4	Morning	30	25.7	140.00	1491	57.98
	Afternoon	30	28.5	126.32	1305	45.79
	Evening	30	28.1	128.00	1533	54.50
4 to 5	Morning	30	21.0	171.43	1115	53.09
	Afternoon	30	25.5	141.41	2101	82.52
	Evening	30	28.9	124.68	1557	53.92

Table-4: Average Speed, Average travel time, Flow and density at congested segments for peak hours (Oil Libya to Agricultural College road segment) on Tuesday

Road Segment	Time	Distance (m)	Average speed (Km/hr.)	Travel time (Sec/Km)	Flow (Vehicle/hr.)	Density (flow*travel time(Veh/km))
2 to 1	Morning	30	30.9	116.67	997	32.31
	Afternoon	30	33.9	106.33	1151	33.99
	Evening	30	26.4	136.59	1622	61.54
3 to 2	Morning	30	29.4	122.63	1586	54.02
	Afternoon	30	15.8	228.57	2385	151.42
	Evening	30	15.2	237.62	1477	97.49
4 to 3	Morning	30	27.0	133.33	1292	47.85
	Afternoon	30	19.1	188.44	2146	112.33
	Evening	30	25.2	142.68	2462	97.57
5 to 4	Morning	30	19.4	186.05	1365	70.54
	Afternoon	30	17.0	212.39	1913	112.86
	Evening	30	28.7	125.65	1359	47.43

Table-5: Capacity and LOS (Oil Libya to Agricultural College road segment) on Tuesday

Road Segment	Time	peak PCU (V)	PHF	vol. during peak hr.	peak min. vol. ¹⁵	DHV (C)	V/C	LOS
2 to 1	Morning	830.5	0.9031	997	276	1104	0.75	C
	Afternoon	999.4	0.8438	1151	341	1364	0.73	C
	Evening	1240.3	0.9842	1622	412	1648	0.75	C
3 to 2	Morning	1231.5	0.9718	1586	408	1632	0.75	C
	Afternoon	2099.8	0.9839	2385	606	2424	0.87	D
	Evening	1359.9	0.9953	1477	371	1484	0.92	E
4 to 3	Morning	1140.5	0.9335	1292	346	1384	0.82	D
	Afternoon	1942.4	0.9991	2146	537	2148	0.90	E
	Evening	2246	0.9992	2462	616	2464	0.91	E
5 to 4	Morning	1227.4	0.9667	1365	353	1412	0.87	D
	Afternoon	1735.8	0.9721	1913	492	1968	0.88	D
	Evening	1148.1	0.9791	1359	347	1388	0.83	D

The same data collection technique was used for Saturday. The following tables show the data collection and analysis of Saturday traffic flow.

Table-6: Directional Hourly traffic volume (Flow) for Mid-Blocks on Saturday

Time	Segment 1to2		Segment 2to3		Segment 3to4		Segment 3to4	
	1 to 2	2 to 1	2 to 3	3 to 2	1 to 2	2 to 1	2 to 3	3 to 2
7:00-8:00 AM	730	708	1014	977	794	912	772	993
8:00-9:00 AM	1247	1132	1588	1716	1491	1423	1250	1495
9:00-10:00 AM	1119	1126	1226	1311	1354	1208	1199	1180
10:00-11:00 AM	1032	1039	1366	1367	1029	1271	1832	1862
11:00 -12:00 AM	1436	1286	2127	2519	1305	2260	2238	2043
12:00-1:00 PM	1288	1387	2118	1670	1456	1879	2219	1957
1:00-2:00 PM	1126	1354	1409	1491	1424	1477	1429	1558
2:00-3:00 PM	1114	1159	1189	1158	1220	1243	1246	1259
3:00-4:00 PM	975	1120	931	960	1031	1171	1131	1221
4:00 -5:00 PM	1260	1218	1261	1290	1342	1753	1317	1440
5:00 -6:00 PM	1987	1751	2440	1652	1533	2518	1535	1495
6:00 -7:00 PM	1193	1026	2096	2011	1016	1656	1310	1307

Table-7: Time Headways at Mid-Blocks (seconds/vehicles) on Saturday

Time	Segment 1-2	Segment 2-3	Segment 3-4	Segment 3-4
7:00-8:00 AM	2.503	1.808	2.110	2.040
8:00-9:00 AM	1.513	1.090	1.235	1.311
9:00-10:00 AM	1.604	1.419	1.405	1.513
10:00-11:00 AM	1.738	1.317	1.565	0.975
11:00 -12:00 AM	1.323	0.775	1.010	0.841
12:00-1:00 PM	1.346	0.950	1.079	0.862
1:00-2:00 PM	1.452	1.241	1.241	1.205
2:00-3:00 PM	1.584	1.534	1.462	1.437
3:00-4:00 PM	1.718	1.904	1.635	1.531
4:00 -5:00 PM	1.453	1.411	1.163	1.306
5:00 -6:00 PM	0.963	0.880	0.889	1.188
6:00 -7:00 PM	1.622	0.877	1.347	1.376

Table-8: Average Speed, Average travel time, Flow and density at congested segments for peak hours. (Agricultural College to Oil Libya road segment) on Saturday

Road Segment	Time	Distance (m)	Average speed (Km/hr.)	Travel time (sec/Km)	Flow (Vehicle/hr.)	Density (flow*travel time(sec/km))
1 to 2	Morning	30	32.4	111.11	1247	38.48
	Afternoon	30	32.4	111.11	1436	44.32
	Evening	30	26.4	136.59	1987	75.39
2 to 3	Morning	30	25.9	139.13	1588	61.37
	Afternoon	30	15.3	235.29	2127	139.01
	Evening	30	15.6	230.77	2440	156.41
3 to 4	Morning	30	25.2	142.68	1491	59.09
	Afternoon	30	24.0	150.00	1305	54.37
	Evening	30	23.7	151.90	1533	64.68
4 to 5	Morning	30	21.5	167.83	1250	58.27
	Afternoon	30	17.1	210.78	2238	131.03
	Evening	30	30.9	116.67	1535	49.74

Table-9: Average Speed, Average travel time, Flow and Density at congested segments for peak hours. (Oil Libya to Agricultural College road segment) on Saturday

Road Segment	Time	Distance (m)	Average speed (Km/hr.)	Travel time (Sec/Km)	Flow (Vehicle/hr.)	Density (flow*travel time(Veh/km))
2 to 1	Morning	30	30.9	116.67	1132	36.68
	Afternoon	30	33.9	106.33	1286	37.98
	Evening	30	26.4	136.59	1751	66.43
3 to 2	Morning	30	29.4	122.63	1716	58.45
	Afternoon	30	15.8	228.57	2519	159.93
	Evening	30	15.2	237.62	1652	109.04
4 to 3	Morning	30	27.0	133.33	1423	52.70
	Afternoon	30	19.1	188.44	2260	118.29
	Evening	30	25.2	142.68	2518	99.79
5 to 4	Morning	30	19.4	186.05	1495	77.26
	Afternoon	30	17.0	212.39	2043	120.53
	Evening	30	28.7	125.65	1495	52.17

Table-10: Capacity and LOS (Agricultural college to Oil Libya road segment) on Saturday

Road Segment	Time	peak PCU (V)	PHF	vol. during peak hr.	peak 15 min. vol.	DHV (C)	V/C	LOS
1 to 2	Morning	1055.8	0.94	1247	331	1324	0.80	C
	Afternoon	1203.9	0.94	1436	381	1524	0.79	C
	Evening	1607.5	1.00	1987	498	1992	0.81	D
2 to 3	Morning	1403.9	0.92	1588	431	1724	0.81	D
	Afternoon	1952	0.99	2127	536	2144	0.91	E
	Evening	2202.9	1.00	2440	610	2440	0.90	E
3 to 4	Morning	1280.3	0.91	1422	390	1560	0.82	D
	Afternoon	2045.5	0.99	2236	562	2248	0.91	E
	Evening	2239.7	0.99	2448	616	2464	0.91	E
4 to 5	Morning	1322.8	0.94	1250	332	1328	1.00	E
	Afternoon	2053.1	0.99	2238	564	2256	0.91	E
	Evening	1245.4	0.89	1535	429	1716	0.73	C

Table-11: Capacity and LOS (Oil Libya to Agricultural College road segment) on saturday

Road Segment	Time	Peak PCU (V)	PHF	vol. during peak hr.	Peak 15 min. vol.	DHV (C)	V/C	LOS
2 to 1	Morning	984.3	0.92	1132	308	1232	0.80	C
	Afternoon	1186.6	0.86	1286	372	1488	0.80	C
	Evening	1433	0.99	1751	443	1772	0.81	D
3 to 2	Morning	1445.3	0.98	1716	439	1756	0.82	D
	Afternoon	2296.4	1.00	2519	632	2528	0.91	E
	Evening	1511.8	0.99	1652	419	1676	0.90	E
4 to 3	Morning	1320.1	0.94	1423	380	1520	0.87	D
	Afternoon	2068	1.00	2260	567	2268	0.91	E
	Evening	2179.3	1.00	2518	630	2520	0.86	D
5 to 4	Morning	1415.1	0.99	1495	379	1516	0.93	E
	Afternoon	1931	0.98	2043	520	2080	0.93	E
	Evening	1355.4	0.99	1495	379	1516	0.89	D

5. Observations from the study

- Volume levels in all the five segments in both directions are high as per its capacity and are increasing between 9 A.M. to 1 P.M. and 3 P.M. to 5 P.M.
- Time Headways are observed to be very small in all the segments in both directions which indicates the intensity of traffic on the segments and are less than 2 seconds in most of the peak hours
- Densities are calculated and are found to be more in all the segments in both directions and is very high between segment 2 to 3 and 3 to 2
- V/C ratio is calculated and the Level of Service is observed to be very poor between the segments 2 to 3, 3 to 4 and 4 to 5 in both the directions
- Flow Ratio is calculated in all the segments in both the directions and is observed to be very high
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6. Recommendations

- On Street Parking shall be controlled strictly with proper parking fee collection
- Road side market and shops shall be managed strictly with staggering of working time
- Public Transportation system should be encouraged
- Pedestrian walkways should be constructed to segregate the pedestrians from regular traffic on the roads
- Hand carts and donkey carts should be diverted by another route in the town
- Roadway width should be increased especially near market places
- Bus station in the town shall be relocated in some other street where roads are less congested
- Heavy vehicles carrying more than 3 tonnes load passing through Oil Libya to Wolaita Sodo University should be diverted to new road from Oil Libya to Wolaita Sodo University via Wolaita Sodo penitentiary
- Another trip attraction arterial road to main market center (Merkato market area) shall be planned

- exclusively from Wolaita Sodo University area and Larena area to Merkato market area
- Main Market center from the town can be planned by the Town planning Municipal authorities to shift to another different area to minimize the congestion on the market road

7. Summery and Conclusions

A study is conducted in Wolaita Sodo town, Ethiopia in order to quantify the congestion on roads under various impacts. The study location is from Agricultural College towards Oil Libya in the town, which is one of the busy area and has impacts such as on street parking, vegetable market, etc. The study location has five road segments which are running with huge traffic everyday both in the morning peak hour and evening peak hour. The traffic data such as traffic volume, speed, time headways are conducted in all the segments of the selected location in both the directions that covers peak hours both in the morning and evening. The data is later analyzed and the various other parameters such as Density, Capacity and Level of Service are determined. The results obtained for different road segments are compared.

After analyzing the Average Speed, Average travel time, density, Traffic Volume, Time Headways, Capacity and level of service (LOS), it can be concluded that the situation on the selected road in all the segments in both the directions is worst throughout the day and is beyond the road capacity. The traffic during morning, afternoon and evening peak hours does not get the required level of service. The increment of road side shops and markets, on Street parking and the mixed traffic flow system are the main factors which resulted in the roadway congestion. The present condition of road needs an immediate attention as it does not provide the required level of service.

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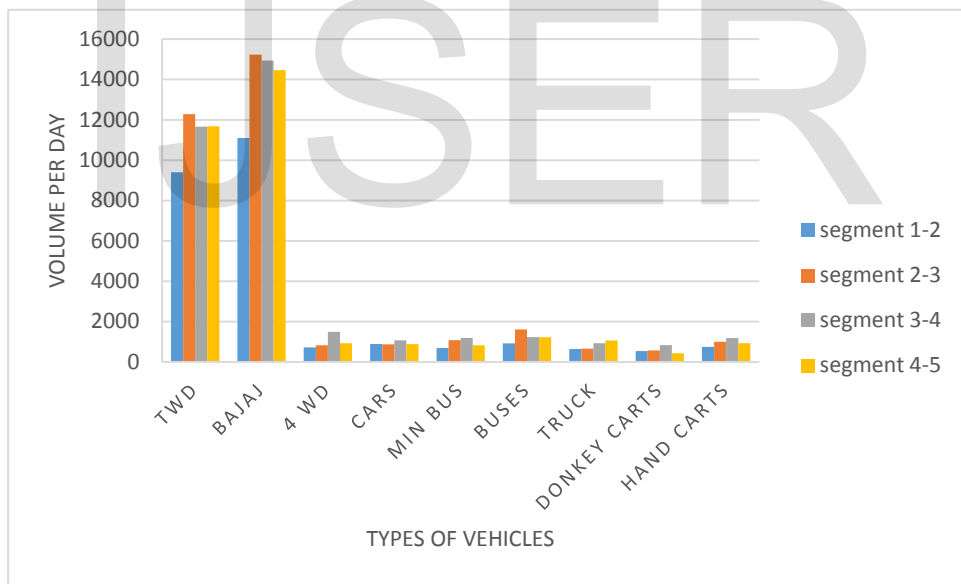


Figure 1. The Total daily volume of each vehicle types

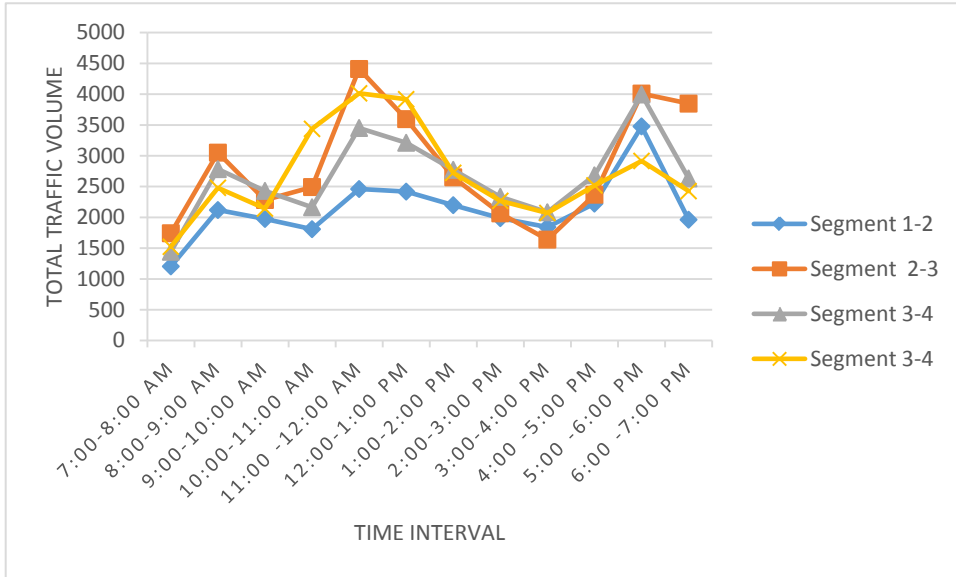


Figure 2. Hourly variation of traffic volume with time (Tuesday)
 Description for the above table 1.

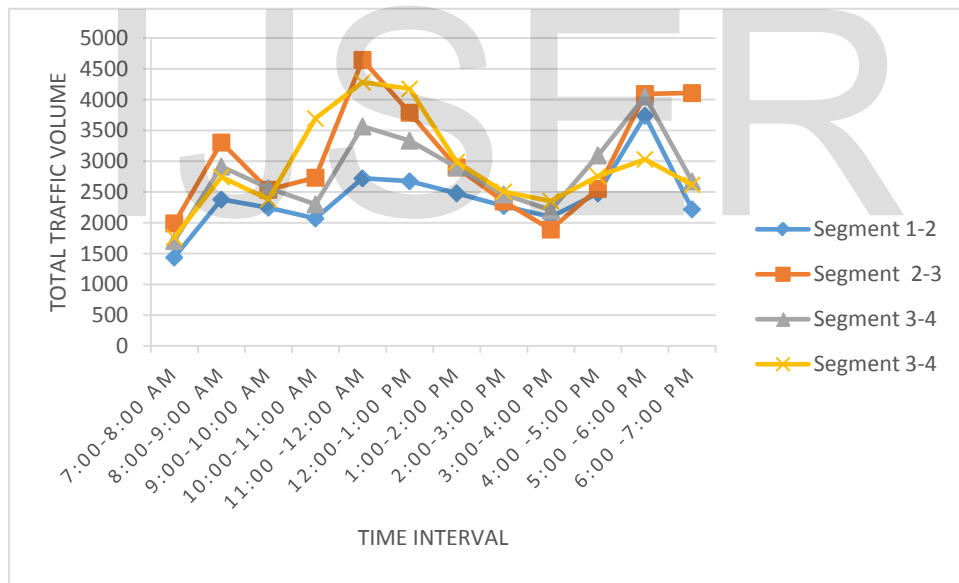


Figure 3. Hourly variation of traffic volume with time (Saturday)
 Description for the above table 8.