

Performance Evaluation of Unsignalized Intersection and Anticipated Alternative Solutions for Designated Corridors in Wolaita Sodo Town

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ABSTRACT

The growth of traffic congestion on many streets, intersections and highways is a major concern to travelers, administrators, merchants, developers and the community at large. Its detrimental impacts in terms of longer journey times, higher fuel consumption, increased emissions of air pollutants, greater transport and other affected costs and changing investment decisions are increasingly recognized and felt across the country. Congestion reduces the effective accessibility of residents, activities and jobs resulting in lost opportunities for both the public and business. This issue is now days a great concern for Ethiopia and major cities in the country. Due to this evaluation of traffic congestion and determination of level of service with the cause of traffic congestion is the first step. From these major cities in Ethiopia, Wolaita Sodo city is now highly observed by traffic congestion especially at intersections. In this paper, first data of traffic volume count, entry time, and departure time and road width collected. Then average traffic speed, traffic volume and traffic headway in terms of level of service and function were analyzed by using HCM-2000 and Microsoft excel sheets for only three most congested intersections.

Keywords: Capacity, Congestion, Intersections, Performance Evaluation

I. INTRODUCTION

The continuous improvements of people's living standards, private cars have become an important means of transportation for many families. As a result, more and more crowded traffic conditions have arisen, especially at road intersections, where congestion is particularly evident. The intersection of urban roads will formed by the convergence of multiple roads. It is the place where the flow of people and traffic flows gathers. It is a crucial link in the transportation system and is the most prone to congestion. Traffic jams at road intersections are commonplace in Beijing, where there are a large number of floating populations and traffic flows. This

has also led to a significant reduction in the efficiency of vehicles, which not only makes it easier to disrupt traffic order, but also causes exhaust emissions to cause air pollution. This requires to effectively alleviating the current congestion situation, not just by limiting line [1].

[9] Said that Intersection is a junction of two or more roads at same or different elevations. In urban and rural road networks, intersections are the key elements of congestion, delay, speed reduction and accidents. Proper studying of existing traffic flow and features of intersection can direct the design, traffic operation and congestion at intersection. Sodo town is a populated town and do not have proper public

transportation system such as RBTS (Rapid Bus Transit System) which is the main cause of increase in number of car owners day to day. Therefore, it is likely to cause congestion at the town roads and intersections.

Traffic congestion is one of many serious global problems of both developed and developing countries. It always exerts a negative externality up on the society. It poses severe threat to economy as well as the environment. Traffic Congestion become common characteristic in urban road transportation system of the cities of developing countries which results in high operation cost, loss of time, high delay, high travel time and increase in fuel consumption [2].

At unsignalized intersection, each driver must find a safe moment for the movement observing current traffic, traffic signs (stop or yield) and pertinent regulations ("right before left"). Accordingly, modeling of operations at an unsignalized intersection is about the interactions between vehicles under the geometric conditions of the intersection. The most important modeling approaches have been stochastic (gap acceptance theory) and statistical (regression analysis) [3]. Finally, this paper focuses on stochastic theory (gap acceptance) to evaluate the performance of unsignalized intersections in terms of actual capacity and lag in time.

A. Background of Study Area

Wolaita Sodo town is located in the strategic place for the southern Ethiopia which located 390 Km of south 167 Km of south west of Addis Ababa and Hawassa respectively. The city is located 6049"N latitude and 37045"E longitude. Based on the 2018 Population Projection by the CSA, this town has a total population of 254,294, of whom 125,855 are men, 128,439 are women, and total area of the town is about 3,200 hectares. This makes Wolaita Sodo town the second most populous city in South Region after Hawassa.

The annual growth rate of the population is 5.4% and has 6 outlets which are connect the north south east and west areas. In recent time, rapid increase in traffic flow activities, economic growth were observed that lead to the level of service and capacity of the roads to decline and drivers not to entertain their flow speed freely with significant delay along the intersection areas.

B. Statement of problem

Major problems of increase in vehicles and lack of traffic control signs and signal System caused high traffic congestion at intersection. This has been primarily in terms of the loss of normal traffic flow, easy and safety of those traversing the intersection while reducing potential conflicts between motor vehicles, taxes, and pedestrians.

Traffic flow capacity at intersection plays a very important role in the transportation network, since they form traffic congestion in urban road network. One of the major parameters at intersection is capacity of traffic flow that is the most important, because it used to determine other parameters at intersections such as saturation flow rate and traffic volume [4]. In Sodo, town traffic congestion at intersection has negative effect on road uses day-to-day activities. This negative effect has caused lack of normal traffic flow of vehicles and safety at existing intersection. Now a day's traffic congestion becomes a serious problem in the town economy growth by limiting the mobility of the road uses and increase delay and fuel consumption especially in local market day.

II. LITERATURE REVIEW

Many studies in the world been conducted on traffic problem in different cities with different set-up, sizes, financial and economic status, thus. This is mainly because traffic studies will always differ from city to

city, depending on the infrastructures, policies, city size, land use and available transport systems. It is therefore, more useful to review different studies on traffic issues and mobility solutions adopted around the urban world and try to blend different ideas to try to establish an appropriate solution.

A. Definition of Traffic Intersection

Traffic flow behavior and pattern either in midblock or intersection, requires quantification of basic traffic flow characteristics and depending upon the width of the road, and traffic flow and composition, speed, volume, density through which the variation in traffic flow characteristics will be assessed. The radical changes in road network and vehicle type also resulted in variations in speed-volume-density characteristics [5] and this is a rapid escalation in the number of motor vehicles in the developing countries (Ethiopia) as a result of various factors such as increase in the purchasing power of common men, the relative reduction in prices and greater availability of used vehicles. It has resulted in greater individual mobility that has caused an increase in congestion [6].

According to [7] Traffic conflicts between vehicular movements created are two or more roads crossed each other. Such conflicts may cause delay and traffic congestion with the possibility of road accidents. Thus, each intersection requires traffic control. It is regulated with stop signs, traffic lights, and roundabouts. The common type of intersection is the unsignalized intersection, which is used to regulate low volume of traffic flow between the major and minor streets. The two-way stop-controlled (TWSC) and all-way stop-controlled (AWSC) are among the types of operation for unsignalized intersection and parallel with WSDOT (2018) Intersections are an important part of highway design which is a general area two or more highway join or cross both roadway and roadside facilities for movement of traffic. Intersection control consideration of all potential

users of the facility, including drivers of motorcycles, passenger car, heavy vehicles of different classifications, public transit, and bicyclists and pedestrians [8].

B. Design Factors of Traffic Intersection

Intersection design is a complex process where factors related to operational efficiency such as capacity, delay and emissions are an important consideration along with safety features and geometrical constraints. A poorly designed intersection may contribute to traffic congestion, increase in vehicular emissions and road accidents. The operational efficiency of intersections largely depends on the prevailing road, traffic and control conditions. In recent years, vehicular emissions have also been a major factor in intersection design [9].

In order to provide guidance on design and evaluation of alternate intersections design, it is critical to identify and understand the factors that affect them. This will facilitate proper design of intersections with suitable geometric characteristics [10]. This basic design factors mentioned below.

-Human factor: - driving habits, decision and reaction time, driver expectancy, ability for drivers to make decisions, conformance to nature path of movement, pedestrian use and habits

-Traffic and safety considerations: -size and operating characteristics of vehicles, design and actual capacities, design-turning movement, variety of movement (merging, diverting, crossing and weaving), vehicles speeds, transit movement

-Physical elements: -conflict area, angle of intersection, vertical alignment, geometric features of characteristics, traffic control devices, environmental factor, sight distance, cross walk, safety features

-Economic Factors: -costs of improvement, effect of controlling or limiting right-of-way, channelization restricts vehicular movements, and energy consumption

-Functional Intersection Area:-Perception-reaction time, maneuver distance, queue-storage distance.

C. Features of Unsignalized Intersection

Unsignalized in traffic engineering simply means without use of traffic signal lights and with stop signs, intersections where signals are no longer functioning (due to loss of power) or intersections where the driver must judge whether stopping is appropriate (at intersections without any traffic control). Since unsignalized intersection is almost the simplest form of intersection in a road network, there were past researches about the topic focusing mostly on factors such as speed, accident and transportation. One of the main weaknesses of an unsignalized intersection is that there is minimal positive indication for the driver to leave or enter an intersection. Stated that to enter an unsignalized intersection, the driver looks for a safe opportunity or "gap" in the traffic [11].

The two broad categories of unsignalized intersection are two-way stop controlled (TWSC) and all-way stop controlled (AWSC). In developing countries mostly (in area of town) two-way stop controlled intersections are highly perceived. Two-way stop-controlled (TWSC) intersections are one of the most common intersection and this type of intersection control is most commonly applied where roads of different functional classification intersection. At TWSC intersections priority provided to the major approach (no traffic control present), while stop signs control vehicular movements on minor approach. Drivers on the minor approach should yield the right of way to traffic on the major road and proceed into the intersection only after a full stop performed. When there is a large, enough gap between two successive vehicles on the major road to safely, execute the maneuver of interest, in such manner that the traffic stream on the mainline remains unaffected [12].

Along with [13]Traffic and transportation in developing countries are also very different to developed countries since traffic composition and level of road side activities are in contrast to developed countries. Traffic rules, for examples, like give way or lane discipline etc. neglected in most cases. Drivers are more aggressive so that a gap acceptance behaviors rather uncommon. In case of unsignalized intersections, almost two third of vehicles did not wait for a gap. If there is any critical gap which is likely to be accepted.

A common situation in any road traffic network is that of an unsignalized intersection that used by two traffic streams, which have different priorities. The priority class consists of cars that arrive, according to some inherently random process, at the intersection; the fact that they have priority essentially means that they cross the intersection without observing the low-priority stream [14].

Again, in area of intersection based on [15]the motorized and non-motorized vehicles have different static and dynamic characteristics. Traffic conflicts that incurred by these vehicles can decrease the intersection capacity. The near-saturation traffic condition impedes vehicular speed between vehicle modes, although motorized vehicles are typically fast moving. Reduced gap between vehicles expected under this occurrence.

Finally, it is important to evaluate the performance of unsignalized intersections in order to perform sufficiently and effectively without any kind of loss of capacity and excessive delay along both in major and minor road along the intersection.

III. METHODS AND MATERIALS

The methodology majorly focuses on selected road sections within Wolaita Sodo town. The collection of data and analysis emphasizes on three selected

unsignalized intersections for performance evaluations and suggest proposed alternatives. The data were taking for three weekday and one weekends, these are Monday, Wednesday, Friday and Saturday. The days were taking based on several field visits and evaluation of study area and design done for representative day that has inclusive for study of traffic problem, efficient number of traffic and mixed type of traffic were observed in the “Fig. 1” below.

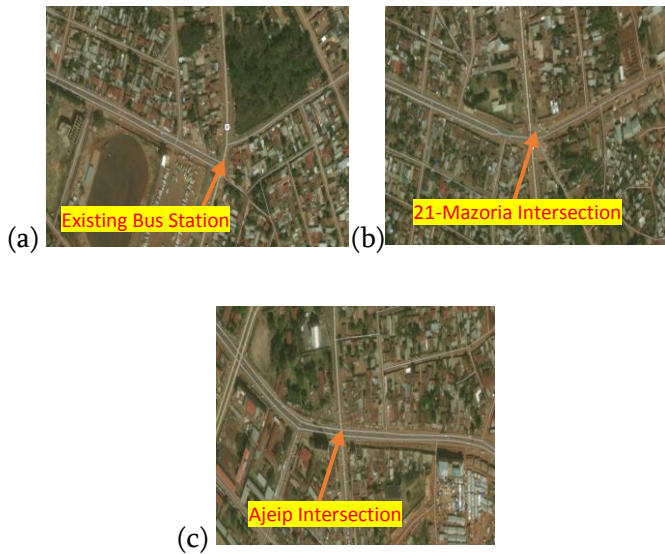


Figure 1: Study Area, (a) Existing Bus Station, (b) 21-Mazoria, (c) Ajeip Intersections

A. Collection of Data

The collection of data for this paper are practical gathering of filed data for selected corridors. Road width, Traffic volume, Traffic speed and minimum gap between consecutive motorized vehicles are used. The data collection tools for this paper are data collection format, digital video camera; fixer and plastic tape are accepted. Three unsignalized intersections selected and Highway capacity manual (HCM-2000) adopted for analysis of collected data’s. The road width and designation of the selected intersection labelled below in Table-1 below.

Table-1: Intersection road width measurement

No	Intersection Name	Legs	Road width(m)
1	Existing Bus Station Intersection	To WSU	12.0
		To Gutara	14.1/2
		To Mariam	12.4
		To Qera	7.3
2	21-Mazoria Intersection	To Markato	8.2
		To Agip	12.0
		To Dream	14.0/2
		To Mariam	12.0
3	Agip Intersection	To Arada	13.9/2
		To Merkato	14.0/2
		To zone admin	12.0
		To Mariam	12.0

IV. RESULT AND DISCUSSIONS

The result and discussions for this paper done based on the collected data.

A. Volume Analysis

Traffic Volume analysis were conducted in three selected unsignalized intersection within Wolaita Sodo City and done for four study days this were Monday, Wednesday, Friday and Saturday. The data taken for selected peak flow period both in Morning and in Afternoon for total of seven hours.

(a) Existing Bus Station Intersection

Volume conducting were done for five Motorized vehicles then the total volume approach wise determined for this Existing Bus Station Intersection and it is possible to determine the total volume(TV) along the intersection and their flow rate in hour. Adopting the passenger car unit of ERA-2013 and their PCU per hour determined to the representative combination of all motorized vehicles used for design. In the “Fig. 2” below the traffic volume along approach, wise in Existing Bus Station Intersection described below for the dominant study day at peak time and in all study days and the motorized vehicles, entering in to Wolaita Sodo University approach was dominant compare to the rest approaches. The volume was high starting to 7:00-8:00 am duration

and gradually results to decline throughout the time interval and then display both decrement and increment. High volume observed were motorized vehicles in Thursday from all study days. In Qera, approach less volume-motorized vehicles observed compare to the others approaches. In traffic, volume of motorized vehicles in all study day displays almost less variation in each study days in this Existing Bus station Intersection. The maximum value in equivalent car unit in Thursday has observed between the duration 3:00-4:00pm has 2126.1pcuhr⁻¹.

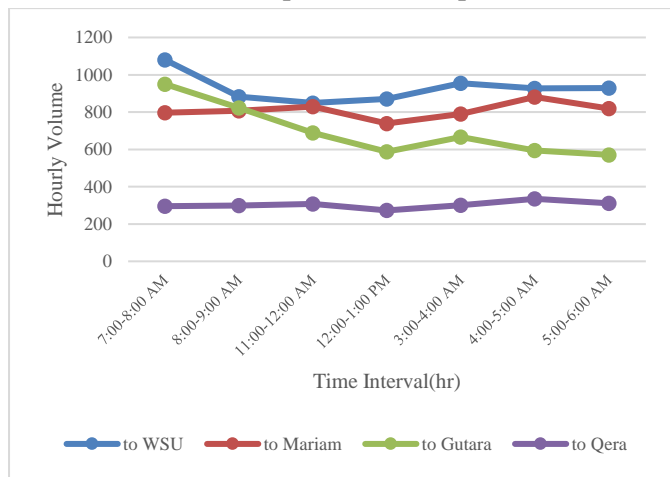


Figure-2: Traffic volume for Existing Bus station in Friday

(b). 21-Mazoria Intersection

The traffic volume along approach wise were described in the “Fig. 3” below for 21-Mazoria Intersection at governing study day at peak time and in all study days the motorized vehicles entering in to Agip approach was dominant compare to the rest approaches. Morning session begin to 7:00-8:00 am duration, the volume was high and gradually results to decline throughout the time interval and then display both decrement and increment. High volumes in motorized vehicles observed in Monday from all study days and 7:00-1:00 pm duration the volume was high (at Morning time).

In Merkato, approach less volume-motorized vehicles observed compare to the others approaches and in Dream and Mariam approaches medium value of traffic volume perceived. In traffic volume of

motorized vehicles in all study, day displays almost have high deviation in each study days in this 21-Mazoria Intersection. After 3:00 pm duration, the volume in Merkato approach became declining in Monday and Wednesday days.

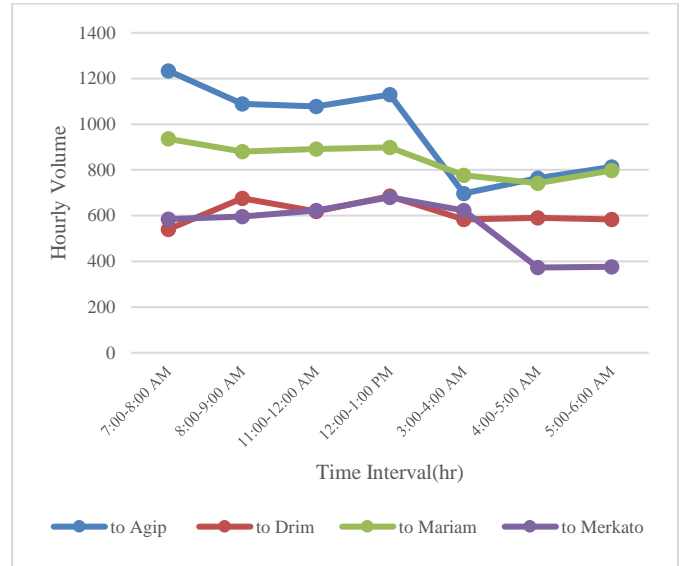


Figure-3: Traffic volume for 21-Mazoria in Monday

(c). Agip around Intersection

In the “Fig. 4” below, traffic volume of motorized vehicles in principal study day all study, day displays almost have less variation in each study days in this Agip around Intersection. In initial duration, the volume was high and gradually results to decline throughout the time interval and less increment. High volumes in motorized vehicles observed in Wednesday from all study days. In Merkato, approach less volume-motorized vehicles detected after 12:00 am duration compare to the others approaches. Between 7:00-1:00 pm time interval the volume in all approach almost constant and after 1:00 pm, duration displays decrease.

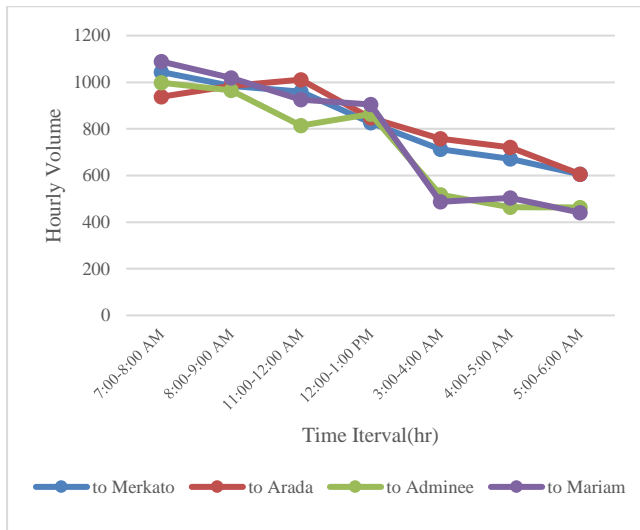


Figure-4: Traffic volume for Agip around in Wednesday

B. Capacity and Level of Service (LOS)

The capacity of the intersections were determined for all approach wise and the service volume to capacity also determined in order to decide the performance of the intersection in each approach based Highway capacity Manual (HCM-2000) then it if possible to categorized their level of service with in hourly interval. The most peak flow selected for this analysis from four study days. In Existing old Bus Station, the capacity in morning time were higher compare to afternoon time and advanced number was displayed in Wolaita Sodo University approach compare to the rest.

The v/c ratio for all four approaches were between 0.79-1.014 and their level service also showed decrement in function and serviceability. In average, their level of service (LOS) was LOS E, which the demand of flow result to governing the capacity of the intersections result to affect comfort and abstain maneuvering of the drivers from the incoming vehicles below in Table-2.

Table-2: LOS for Existing Bus Station at Friday

Time	LOS			
	to WSU	to Mariam	to Gutera	to Qera
7:00-8:00 AM	E	E	E	E
8:00-9:00 AM	E	F	E	D
11:00-12:00 AM	D	E	E	E
12:00-1:00 PM	D	E	D	E
3:00-4:00 AM	E	E	E	E
4:00-5:00 AM	E	D	C	E
5:00-6:00 AM	E	E	D	E

While, in 21-Mazoria Intersection the hourly capacity were more between 7:00-8:00 am from the rest duration in all approach and volumes entering in to Agip approach is advanced. In Table-3 below for all four approaches The V/c ratio were between 0.779-0.973 and similar to the above intersection their level service showed decrement in occupation and serviceability. In average their level of service (LOS) was LOS E which capacity was became less compare to demand of flow of the intersections and LOS D were medium observed in each approach.

Table-3: LOS for 21 Mazoria Intersection at Monday

Time	LOS			
	to Agip	to Drim	to Mariam	to Merkato
7:00-8:00 AM	D	D	E	E
8:00-9:00 AM	E	D	D	D
11:00-12:00 AM	E	E	E	D
12:00-1:00 PM	E	E	E	D
3:00-4:00 AM	D	D	C	E
4:00-5:00 AM	D	E	D	E
5:00-6:00 AM	E	E	E	D

In Agip around Intersection the hourly capacity were more between 7:00-8:00 am from the rest duration in all approach and volumes entering in to Merkato approach was advanced in Table-4 below for all four approaches The V/c ratio were between 0.847-1.00 and similar to the above intersection their level service also showed declines in function and serviceability. In average, their level of service (LOS) was LOS E which capacity was became less compare to demand of flow of the intersections.

Table-4: LOS for Agip Intersection at Wednesday

Time	LOS			
	to Merkato	to Arada	to Adminnee	to Mariam
7:00-8:00 AM	D	E	D	E
8:00-9:00 AM	E	E	D	E
11:00-12:00 AM	E	E	D	E
12:00-1:00 PM	D	E	E	E
3:00-4:00 AM	E	E	E	E
4:00-5:00 AM	E	E	E	F
5:00-6:00 AM	E	E	C	D

In Existing Bus Station,21-Mazoria and Agip around Intersection were displayed their capacity volume and level of service(LOS) in vulnerability boundary(stage) due to further increment in demand of flow in this intersections result the LOS entering traffic jam situation and the level of delay also became dominant.

C. Traffic speed Analysis

Based on the data collected the traffic speed analysis done and their respective level of service (LOS) made using traffic speed adopting HCM-2000.

(a). Existing Bus Station Intersection

In Existing Bus station intersection, the level of service(LOS) for three approaches (Agip, WSU and Gutera) is very poor but in Qera approach due to there is less flow of motorized vehicles especially in medium trucks and heavy trucks shown in “Fig. 5,” which result drivers to entertain their flow speed. When comparing this intersection with the other two intersections in relative, their average traffic speed is moderate.

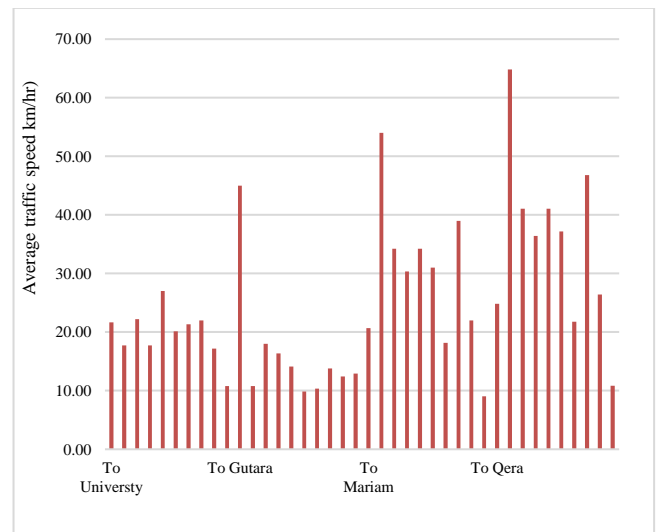


Figure-5: average speed variation in Existing Bus station

(b). 21-Mazoria Intersections

The average speed in 21-mazoria intersection for all approaches designates not consistence and indicates that in two approaches (Mariam and Agip) highly congested and the other two approaches (Dream and Merkato) the traffic speed is moderately high and displayed in the “Fig. 6”. The level of service in four approaches based the average speed is uneven and the overall level of service is LOS-F which the performance of the road enter to congested stage.

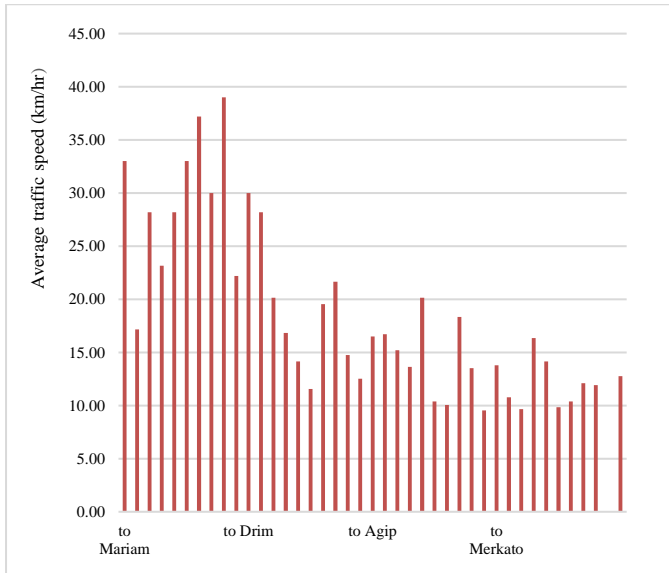


Figure-6: average speed variation in 21-mazoria

(c). Agip Intersections

In Agip, intersection for all approaches indicates that their average speed is not consistence and the overall level of service (Mariam, Arada, Merkato and zone administration) goes to LOS-F, which is highly congested displayed in the “Fig. 7”below. In general, the Level of Service (LOS) in terms of serviceability and function caused the existing traffic flow in all intersection as problem of traffic congestion, irregular traffic flow and delay.

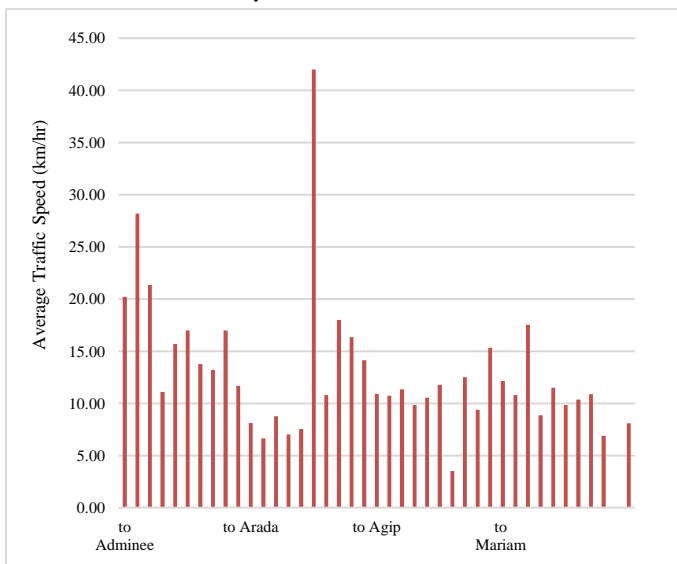


Figure-7: average speed variation in Agip intersection

D. Traffic Headway (gap) Analysis

The average headway for selected three intersection of different legs done at Monday and Saturday. In

Monday, at intersection of Existing Bus station for leg to WSU has minimum average headway (gap) value (moderate traffic speed and high traffic flow), and in Agip intersection for leg to zone administration has moderate value (high traffic speed and moderate traffic flow) compare to each other.

Whereas, in Saturday Existing Bus station intersection for leg to WSU has also minimum average headway (low traffic speed and high traffic flow), and for leg to Gutara has moderate average headway (high traffic speed and moderate traffic flow). The average headway (sec) labelled in “Fig. 8”below for all approach.

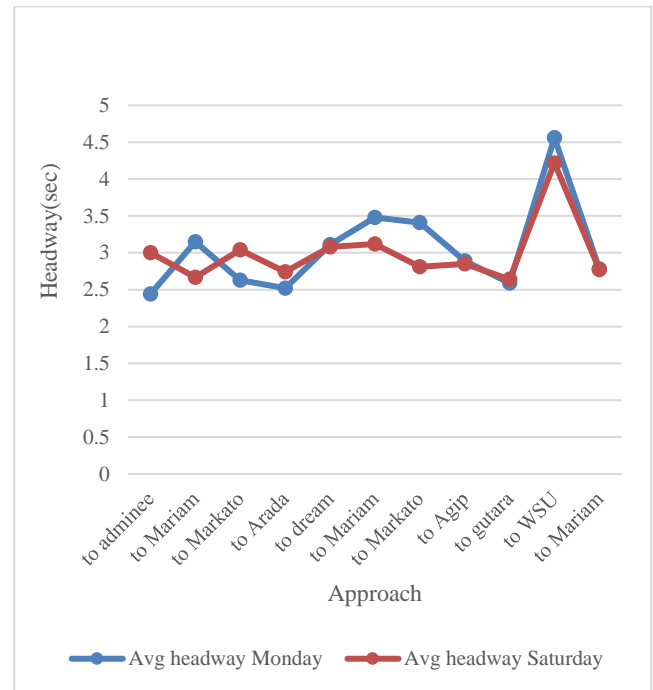


Figure-7: Average headway in all intersections leg-wise

E. Proposed Alternative Solutions

(a) Existing Bus Station Intersection

In Existing Bus station, the road is narrow compared with the other two intersections (21-mazoria and Agip) and the overall level of service (LOS) is F and illegal parking near to intersection is high which result traffic interruption along the approaches. Due to this, the proposed alternative solution is avoiding illegal parking around intersection, installing traffic signals, diverting traffic flow especially for small

vehicles (Bajaj, motorcycles), providing parking area away from the intersection and constructing pedestrian way along the approaches to Mariam to Qera and to WSU intersections legs.

(b) 21-Mazoria Intersection

Comparing 21-mazoria intersection than other two intersections (Agip and existing bus station), the road is relatively wider than Existing Bus station intersection and similar to Agip intersection and in terms of Level of service with respect to traffic volume and average speed, the performance of the road is below the capacity and un-desired LOS. The proposed solution in order to balance the function and serviceability of the road with the flow of traffic are it needs to divert small vehicle category(Bajaj and motorcycles) to other flow direction(route), installing traffic signals, avoiding illegal parking around the intersection and providing parking area away from the intersection.

(c) Agip intersection

The width of road in Agip intersection compared to the other two intersections (existing bus station and 21 mazoria) it is moderately wider than both intersections but at peak time that is 1:30-2:00 A.M and 11:00-12:00 PM the road is highly congested by vehicles and pedestrians. To avoid this, the anticipated alternative solution is installing traffic signals and constructing pedestrian walkway is better to reduce this problem. In addition to this the level of service in terms of road width to serve the traffic volume is below the demand traffic flow, Therefore redesigning the existing intersection, installing traffic signals, avoiding illegal parking near to the intersection and diversion of traffic flow to other route are best alternative solution for this intersection .

In general, for three intersections the proposed alternative solutions to reduce the complications of the existing traffic flow conditions are installing traffic signals, diverting traffic flow, avoiding parking

around intersection, constructing pedestrian walkway are the short term solutions. For long-term solution, redesigning of existing intersection must be adopted.

V. CONCLUSION

Traffic flow activities are increasing rapidly because of various activities and this impose additional load, which result traffic flow interruption, flow disturbance, traffic congestion and declined level of service (LOS) at unsignalized-intersection in each approach and overall. The performance of unsignalized-intersection have major impact on the serviceability and function of legs (approach) of the road. Therefore, it should be evaluated in accordance in order to determine their flow parameter and level of service at operation period.

All three selected unsignalized-intersections are evaluated from composed data of volume, speed and average gap between consecutive vehicles in leg-wise and analysis is done. In all selected unsignalized intersection the overall level of service fall LOS-D to LOS-F, which displays that their performance is declining gradually. Due to this, various complications in all unsignalized-intersection are highly observed with their respective approaches. Finally, to counterbalance this all impact for unsignalized intersections in Wolaita Sodo town all proposed anticipated solutions should be adopted for the future.

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