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Validating the Warrants for Installing or Removing Traffic Signals at Selected Intersections in Hawassa City

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Abstract

Signalized and non-signalized intersections are checked for their traffic flow for both vehicular as well as pedestrian volume for assurance of the installation or removal of traffic signal. This would ensure a smoother traffic flow specifically in the intersection site and on the road network and reduces delay and accident rates thereby helping the users. The major objective of this study is evaluating the warrants for traffic signalization or removal for both non-signalized and signalized intersection respectively. If a warrant exists to use traffic signal control in signalized and non-signalized intersection, an update for traffic signal timing is suggested as the old traffic count is different from the contemporary one. Highway Capacity Manual 2000 and Manual on Uniform Traffic Control Devices (MUTCD) is used for procedures and analysis. As MUTCD states, Warrants 1 through 9 is checked for both signalized (Near Daetie) and non-signalized (near Aroge Gebeya) intersections. To check the warrants, a 12-hour traffic data is collected from both intersections for vehicular as well as pedestrian for a weekday and a weekend. All vehicular and pedestrian volume count and geometric data required for the analysis of signal warrants and signal time design is recorded using video recorder and manually counted on sheets at desk in the office. The vehicular traffic data is collected on February 06, 2024 on Tuesday. 18,160 and 25,242 vehicular traffic are collected for Gebeya and Daetie intersections respectively. Both intersections are warranted for signalizations since the 8 hour, 4 hours, peak hour warrants and pedestrian volume warrants are satisfied for both cases. After the warrants are checked, the signal time update was conducted for Daetie intersection and the optimum cycle time found was 72 seconds.

Keywords: Traffic Signal Warrants; Signalized Intersection; Webster Method; Hawassa City.

1. Introduction

Traffic operation and control measures are the basic components of any urban transportation system. Elements like traffic signs, signals, road markings, and operational controls play a crucial role in ensuring the safe and efficient movement of vehicles and pedestrians (Robert F. B., 1975). Among these, traffic signals represent the highest form of traffic control, particularly at intersections where traffic movements converge and conflicts are most likely to occur.

Traffic signals are widely analyzed forms of intersection control across many countries. While non-signalized intersections remain more numerous, signalized intersections dominate in areas with high traffic volumes, where effective regulation of vehicular and pedestrian flows is essential (Findley et al., 2015). Due to the complex nature of conflicting movements, intersections are often associated with higher crash frequencies and vehicle delays (Mannering & Washburn, 2020). Although most intersections operate safely without signalization, increasing traffic volumes, accident rates, and pedestrian activities may eventually justify the installation of traffic signals.

The implementation of traffic signals offers several advantages, including a reduction in right-angle crashes, improved pedestrian crossing opportunities, enhanced side-street access, better coordination along traffic corridors, and potentially reduced delays. However, traffic signals are not a universal solution and can introduce disadvantages such as increased rear-end collisions, unnecessary delays, and inefficient traffic progression when improperly installed or timed (Traffic, 2009). Hence, regular evaluation and validation of existing signals are essential to ensure they remain justified under current traffic conditions (Imran & Ewadh, 2020).

The Manual on Uniform Traffic Control Devices (MUTCD), developed by the Federal Highway Administration (FHWA, 2009), provides comprehensive guidelines for the design, installation, and maintenance of traffic control devices. The MUTCD comprises nine parts, covering all aspects of roadway control devices—from signs, markings, and traffic signals to temporary traffic control and specialized applications such as school zones and bicycle facilities. In particular, Part 4 outlines the procedures and criteria for the installation of highway traffic signals.

According to the MUTCD, the installation or removal of a traffic signal must be supported by an engineering study that considers roadway characteristics, traffic volumes, pedestrian and cyclist activity, and safety performance. This study forms the basis for determining whether the minimum conditions—or warrants—for traffic signal control are satisfied. Furthermore, continuous monitoring and periodic re-evaluation are necessary to determine whether existing signals remain warranted or require modification. If traffic patterns change significantly and the warrants are no longer met, the removal or retiming of signals should be considered.

In this context, intersections in Hawassa City present critical points in the urban transport system where the justification for existing or proposed signalization must be evaluated. Specifically, for intersections with existing traffic signals, it is essential to assess whether updated signal timing or phasing is required due to changing traffic volumes. Similarly, for non-signalized intersections, it is necessary to determine whether current traffic conditions warrant the installation of signals based on MUTCD criteria.

Rapid urban growth and motorization in cities such as Hawassa have led to increased traffic congestion, delays, and accidents. Consequently, many intersections have been signalized to manage these challenges. However, improper or unjustified installation of traffic signals can worsen intersection performance, leading to excessive delays, increased rear-end collisions, and disobedience of signal indications. Poorly timed signals can also disrupt coordinated traffic flow and divert vehicles to unintended routes through residential areas.

As noted by Robert F. B. (1975), many signals have been installed where no genuine need exists; resulting in unnecessary costs, increased delays, and higher crash rates. Given that traffic signals are expensive to install—often exceeding $100,000 (approximately 15 million ETB during study period's exchange rate)—their implementation must be supported by thorough engineering studies. The MUTCD (2009) outlines eight principal warrants that guide this process, including considerations of vehicle and pedestrian volumes, crash experience, and coordination needs.

Therefore, this study focuses on evaluating the current traffic conditions at two key intersections in Hawassa—one signalized (near Daetie) and one non-signalized (near Aroge Gebeya)—to determine whether they meet the MUTCD warrants for signalization or continued operation under existing control.

Assessing the warrants for signalization at both signalized and non-signalized intersections provides critical insights into the appropriateness of current control systems. For existing signalized intersections, this evaluation helps determine whether current traffic volumes justify continued operation or require retiming to improve efficiency and reduce delays. For non-signalized intersections, it helps identify locations where signal installation may enhance safety and operational performance.

By conducting an engineering study of traffic, pedestrian characteristics, and roadway geometry, the research supports data-driven decision-making in intersection management. This approach ensures that signal installations and timings align with current traffic demands, thereby minimizing unnecessary delays, discouraging disobedience of signals, preventing the use of inappropriate routes, and reducing collision frequency.

The general objective of this research is to validate the warrants for the installation, removal, or retiming of traffic signal controls at selected intersections in Hawassa City. The specific objectives are to assess current traffic conditions through traffic count surveys at selected signalized and non-signalized intersections, to determine whether these intersections satisfy MUTCD (2009) signal warrants, and to update or redesign traffic signal timing for warranted signalized intersections based on contemporary traffic volumes.

2. Materials and Methods

2.1. Study Area

The intersections selected are found in Hawassa city (Ethiopia) that is the capital in the Sidama Regnal state, 273 km south of Addis Ababa (capital of Ethiopia).

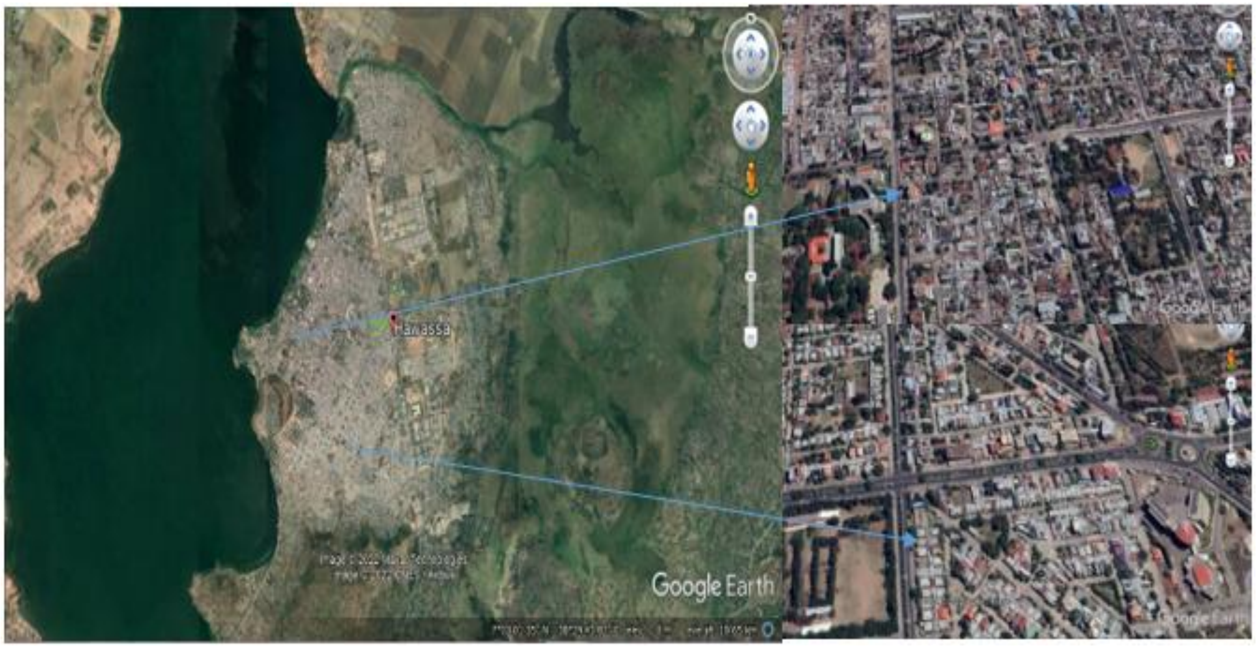

Figure 1. Map of the study area (Google Earth Pro 2022

The city is located at latitude 7°, 3′43.4” and longitude N 38°28′34.9’’E Coordinates and an elevation of 1708 meter respectively. The city is surrounded by Loke village in the West, Oromia Region in the North, Wondo Genet woreda in the East, and Shebedino woreda in the South. Source: (City administration of Hawassa, 2014). The intersections are located at Near Daetie (Signalized) and Near Arogemeneharia (non-signalized).

2.2. Study Subject

As the objective of this research is to check the warrants set by MUTCD manual for signalization of non-signalized intersections or removal of signal control from signalized intersections, traffic counting is a first step to this kind of problem solving which includes both vehicular count and pedestrian count. After the traffic flow rate count, requirements for signalization has to be checked for both types of intersections before installing or removing signal controls. Video camera was used for traffic count data at the two study sites/intersections on weekdays during the maximum 12 hrs traffic count. This 12 hrs traffic count may fall at any time within the 24 hours that includes both morning and evening peak periods.

2.3. Study Design

This is a case study of checking the warrants of both signalizing as well as removing the signal at selected at grade intersections located near Woldeamanuel roundabout and near Arogemeneharia intersection respectively. The reason for selecting the above two intersections is due to the result of the reconnaissance study. This study reveals that there is less traffic flow for near Woldeamanuel roundabout intersections while there are more traffic flows on the near Arogemenehari intersection. This reconnaissance survey should be confirmed through a rigorous study though.

The results that would be obtained might help policy makes in evaluating the other intersections before installing or removing traffic signal at intersections for smooth flow of traffic as well as traffic delay reduction. The validity of the research results might be confirmed or validated with other similar type of traffic data.

2.4. Study Methodology

The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location (namely near Daetie and near Gebeya) and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants. As the warrants are listed and taken from MUTCD manual part 4 ,“Warrant 1 Eight-Hour Vehicular Volume, Warrant 2 Four-Hour Vehicular Volume, Warrant 3 Peak Hour, Warrant 4 Pedestrian Volume, Warrant 5 School Crossing, Warrant 6 Coordinated Signal System, Warrant 7 Crash Experience, Warrant 8 Roadway Network, Warrant 9 Intersection near a Grade Crossing/Railway crossing” (Traffic C, 2009).

For signal warrants requiring conditions to be present for a certain number of hours in order to be satisfied, any four consecutive 15-minute may be considered as 1 hour if the separate 1-hours used in the warrant analysis do not overlap each other and both the major-street volume and the minor-street volume are for the same specific one-hour periods. For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians. When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.” (Traffic C, 2009

2.5. Data Collection

For signal warrants that specify traffic conditions must be met for a certain number of hours, any sequence of four consecutive 15-minute intervals may be considered equivalent to one hour, provided that the selected one-hour periods do not overlap and that both the major- and minor-street volumes correspond to the same specific one-hour intervals. In conducting signal warrant analyses, bicyclists may be classified as either vehicles or pedestrians, depending on their mode of operation. Typically, bicyclists traveling within the roadway alongside vehicular traffic are counted as vehicles, whereas those using designated pedestrian pathways are counted as pedestrians.

The necessary data that would be collected from both intersections is listed below

- The average day number of vehicles crossing the intersection for 12 hours
- Pedestrians crossing the intersections during vehicular count
- Posted speed limit or the 85th percentile speed
- Physical layout of the intersections including lane dimensions
- Crash data using collision diagrams if available

Traffic data collection included identifying peak and off peak hours and pedestrian volumes. Video techniques were utilized for collecting vehicular and pedestrian volumes within the study area for peak hours and manual traffic count is conducted for the rest of 12-hour off peak periods for average day per intersection. The average day is considered to be Tuesday, Wednesday or Thursday. According to Gene Hawkins et al. (1998) “an "average" day is defined as a weekday representing traffic volumes normally and repeatedly found at the location”. “In practice, analysts typically perform a traffic count on a typical weekday, which often avoids Monday and Friday, as well as any holidays” (Findley et al., 2015).

The video technique is believed to be a trustworthy for several reasons. The films can be watched at any time and reviewed, reduces human error, and the cameras can be located in high areas to record wide range of the study area. Consequently, highway users are not easily confused and the films produced will be more accurate and reliable.

The other important parameter in determining the warrants for intersection signals is the number of lanes and how it is going to be counted. (IRC) The Indian Roads Congress (2010) suggests to each intersecting traffic lane to have a minimum of 2.8m width. The site-specific traffic characteristics should dictate whether an approach is considered as one lane or two lanes. The traffic lane near the intersection might be counted as one lane or two lanes based on the turning vehicular traffic volume and its impacts on the opposing traffic (Traffic, 2009).

The MUTCD does not explicitly specify passenger car equivalent (PCE) values for heavy vehicles such as trucks and buses; however, it does not prohibit their application in signal warrant analyses when supported by sound engineering judgment and empirical studies. Consequently, vehicular counts in this study represent the total number of vehicles of all types using the intersection to traverse or cross. (Source: MUTCD, FHWA, 1997)

3. Results and Discussion

3.1. Current Traffic Condition

All vehicular and pedestrian volume count and geometric data required for the analysis of signal warrants and signal time design is recorded using video recorder and manually counted on sheets at desk. 18,160 and 25,242 vehicular traffic are collected for Gebeya and Daetie intersections respectively. Table 1 shows a summarized 12-hour traffic count (after adding the 15-minute traffic) for both intersections. The vehicular traffic data is collected on February 06, 2024 on Tuesday.

Table 1. Summarized 12 - Hour traffic count

Hourly traffic count of Gebeya intersection				
Time	**To Piassa**	**To Arebsefer**	**To South Star**	**To Gebeya**
12:00-1:00	251	184	39	81
1:00-2:00	546	481	142	204
2:00-3:00	761	588	232	274
3:00-4:00	634	582	217	353
4:00-5:00	499	514	215	144
5:00-6:00	456	536	295	185
6:00-7:00	535	536	234	347
7:00-8:00	609	607	319	532
8:00-9:00	649	579	393	311
9:00-10:00	614	701	341	185
10:00-11:00	441	374	315	350
11:00-12:00	293	189	148	145
Total	**6288**	**5871**	**2890**	**3111**

The vehicular composition of the traffic in Daetie intersection is presents as follows in Fig 2. Two wheelers consist of 39%, four wheelers consist of 43 %, three wheelers consist of 11% and Heavy vehicles consist of 7%. Among the heavy vehicles, most of them are using the main road.

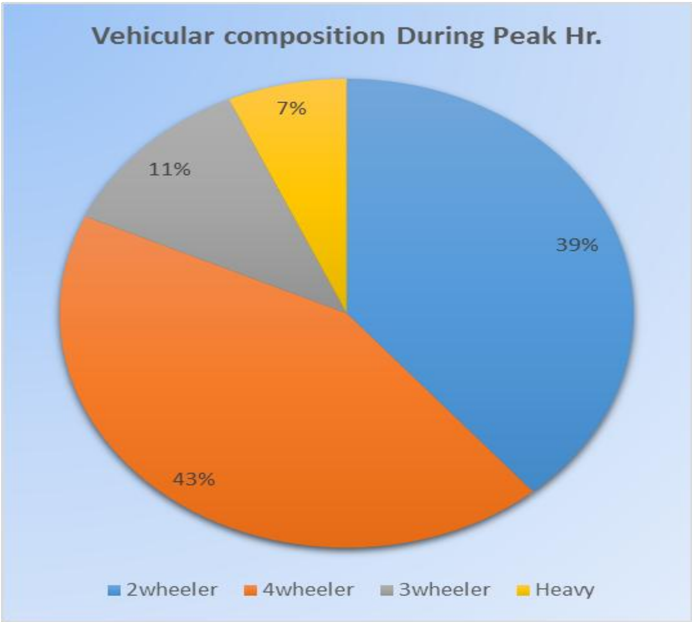

Figure 2. Vehicular composition during peak hour

The second type of traffic which is used for checking the warrant is the pedestrian volume count in the peak hour of the 12 hours. Table 2 indicates a total of 338 pedestrians and 422 pedestrians were crossing the major road of Daetie and Gebeya intersections. Both intersections are highly utilized in terms of pedestrian traffics.

Table 2. Peak hour Pedestrian volume

Time (Peak Hour)	Pedestrians crossing all major road Daetie	Pedestrians crossing all major road Gebeya
2:00-2:15	101	102
2:15-2:30	93	121
2:30-2:45	80	105
2:45-3:00	64	94
Total	**338**	**422**

Sample data collected from video recording is presented in the table 3.

Table 3. Sample data collected in Daetie signalized intersection from 7 to 8 afternoons

Period	To stadium	to Diaspora	to Rori	to Gezahegn
7:00-7:15	83	112	166	108
7:15-7:30	82	121	150	109
7:30-7:45	78	131	148	121
7:45-8:00	85	145	139	128
Total	**328**	**509**	**603**	**466**

3.2. Geometric Data

The geometric data which are the number of traffic lanes and their width helps in warrant evaluation. Geometric data were gathered using a mixture of several techniques. Initially, satellite images using google earth were used to obtain the required data such as lane width, the angle of intersection, and the four approaches. Later lane widths are measure on the field using measuring tape Gebeya Intersection. This intersection is a four-legged 1 lane intersection located near Aroge Gebeya (Old Market). Table 4 shows the geometric data related to A. Gebeya intersection.

Table 4. Lane width and number of lanes for Gebeya intersection

Approach	Lane Width	Number of Lane
Areb Sefer	3.4m	1
Piassa	3.4m	1
Gebeya	3.3m	1
South Star	3.3m	1

Daetie Intersection

This is a four legged multilane signalized intersection located near Daetie Hotel and President Office. Table 5 shows the features of Daetie intersection and pictorially in Figure 3.

Table 5. Lane width and number of lanes for Daetie intersection

Approach	**Lane Width**	**Number of Lane**
Stadium	3.2m	2
Diaspora	3.2m	2
Rori	3.6m	3
Gezahegn	3.6m	3

3.3. Eight Hour Warrant in Gebeya Intersection

Selecting the major and minor street is the first step in checking the warrants after collecting the traffic data. In in the four legged Gebeya intersection approaches to Piassa and Arebsefer are selected as major street as their combined traffic is higher than the combined traffic of approaches to Southstar and Gebeya.

Table 6. The two major road combined volume and higher volume minor road volume in Gebeya intersection

Minimum Vehicular Volume		
Vehicles per hour on major street (Total of both approaches)	**Vehicles per hour on Higher-volume minor- street approach (one direction only)**	**100%**
435	81	No
1027	204	Yes
1349	274	Yes
1216	353	Yes
1013	215	Yes
992	295	Yes
1071	347	Yes
1216	532	Yes
1228	393	Yes
1315	341	Yes
815	350	Yes
482	148	No
Condition Required		8 times
Condition Met		10 times
Warrant		Met

The maximum combined vehicles per hour existed in between 2 to 3 hours in the morning on the major road and the maximum hourly volume is recorded on the afternoon between 8 to 9 O'clock in local time on the minor road. Here the peak hour is set based on the major traffic as between 2 to 3 O'clock. As can be seen from the table 6, warrant 1 is met at 100% (Basic minimum hourly volume) using Condition A(minimum vehicular volume) for Gebeya intersection for hours from 1:00 to 11:00 O'Clock

The major street in Daetie intersection is the approach from Rori to Gezahegn as can be understood from the number of vehicular traffic as well as the number of the lanes. Similar to Gebeya intersection the peak hour for Daetie intersection existed between 2 to 3 o'clock as the highest vehicles per hour is existed which is 1285 vph amongst the other 12 hours. As can be seen from the table 1, warrant 1 is met at 100% for Daetie intersection for 11 times from 1 to 12 o'clock.

Table 7. Traffic volume and 8 Hour Warrant in Daetie Intersection

Vehicles per hour on Main road (Total of both directions)	**Vehicles per hour on higher-volume minor-road direction (one direction only)**	**100%**
644	581	no
1184	1319	yes
1285	1278	yes
1044	818	yes
909	622	yes
1027	563	yes
1040	721	yes
1069	509	yes
1104	689	yes
969	608	yes
1033	459	yes
1053	440	yes
Conditions required		**8 times**
Conditions met		**11 times**
Warrant		**Met**

3.3.1. Warrant 2: Four Hour Volume warrant

All the combinations of Minor Street higher volume approach vehicles per hour volume and major street total vehicles per hour volume are well above the line indicated by the arrows for Daetie and Gebeya intersections as shown in fig 4. This indicates the four-hour volume warrant is met for both intersections.

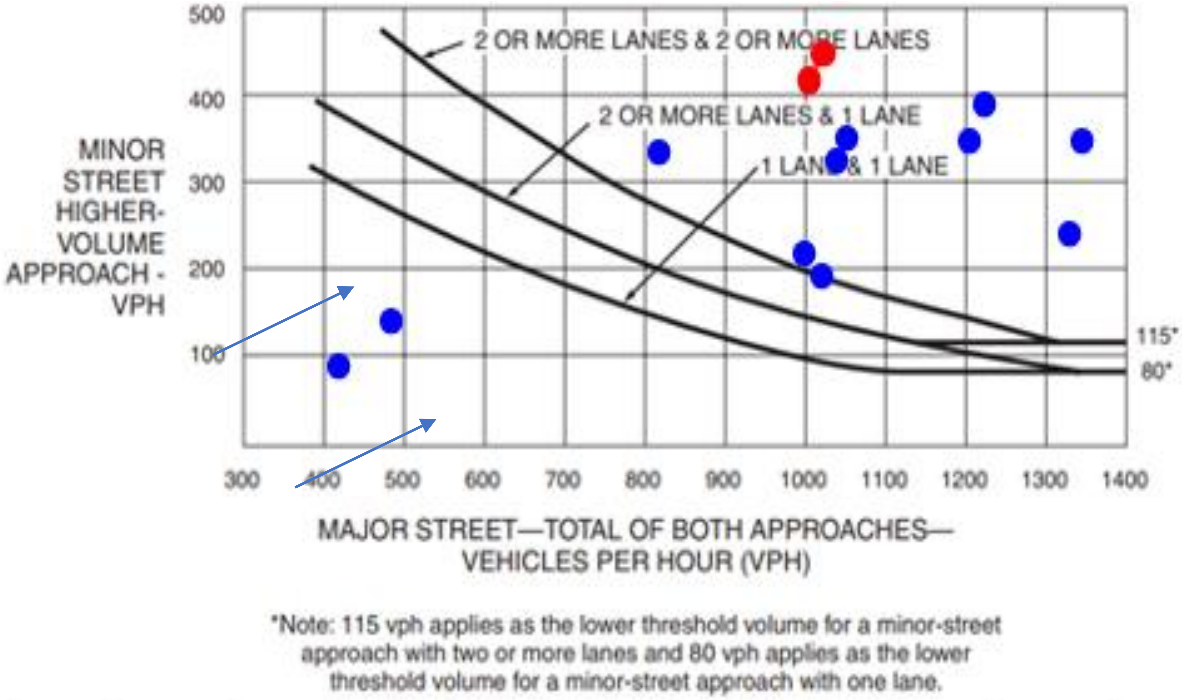

Figure 3. Warrant 2 four hour vehicular volume

3.3.2. Warrant 3, Peak Hour

The Peak Hour signal warrant is used at intersection where traffic volumes are such that for a minimum of peak hour of an average day, the minor-way traffic suffers excessive delay when crossing the major highway.

By applying the highest traffic volume on the warrant curve for peak hour (for both morning and afternoon peak), the peak hour traffic warrant can be checked. The morning peak exists from 2:00 to 3:00 (8:00-9:00 AM) and the afternoon peak exists from 9:00 to 10:00 (3:00-4:00PM) for Gebeya Intersection while the morning peak exists from 2:00 to 3:00 (8:00-9:00AM) and the afternoon peak exists from 8:00 to 9:00 (2:00-3:00 PM) for Daetie intersection.

Peak Hour warrant is met for both Gebeya and Daetie Intersections as indicated from the plotted points on the warrant curve in Figure 5.

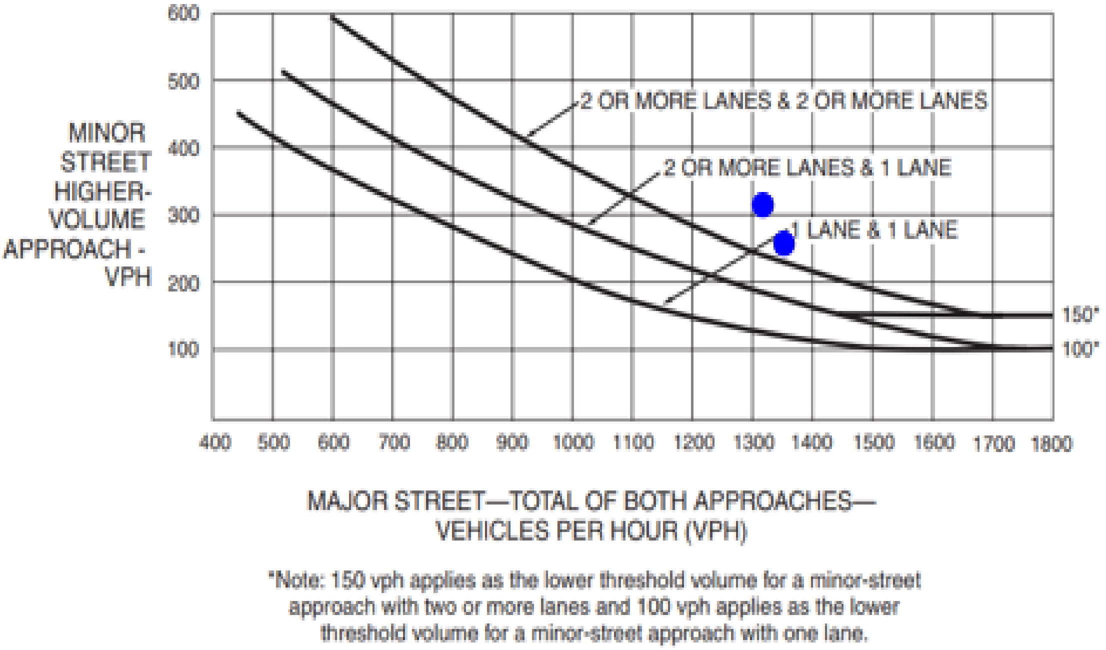

Figure 4. Peak Hour Warrant

3.3.3. Warrant 4, Pedestrian Volume

The Pedestrian Volume signal warrant is applied where the traffic volume on a major road is high that pedestrians are obliged to stand on walkway for so long. There are two ways of checking this warrant. One by counting a four hour pedestrian and major road traffic volume and the other is counting the pedestrian and major road pedestrian traffic volume for peak hour. In this research we checked the peak hour pedestrian warrant. The warrant is met if one of the conditions is met.

As can be seen from the plotted points in figure 6 the signal warrant for pedestrian volume is met as the points are well above the curve.

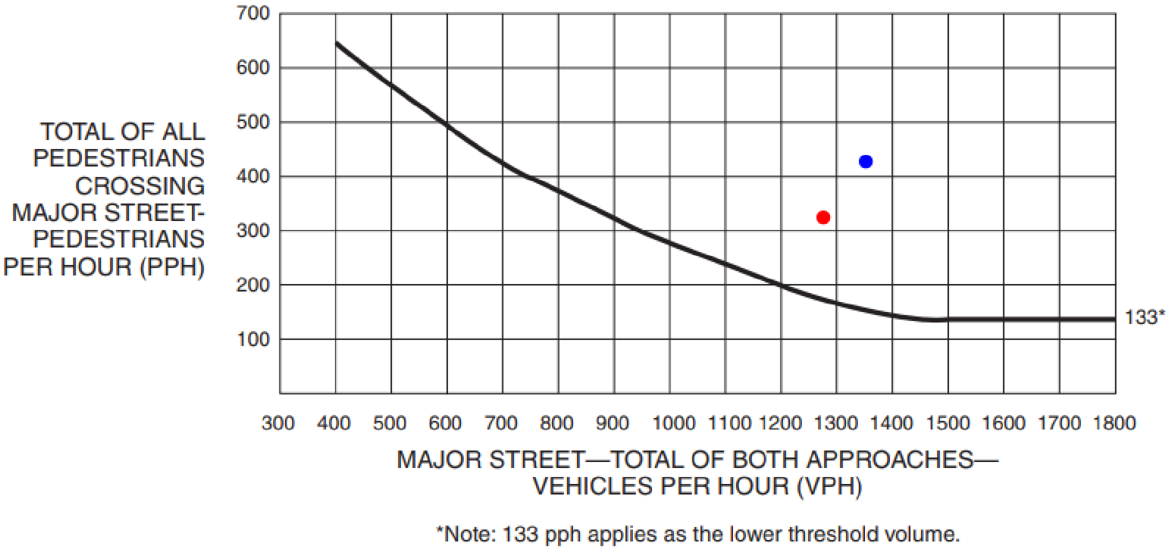

Figure 5. Peak pedestrian warrant Red for Gebeya and blue for Daetie

3.3.4. Warrant 5, School Crossing

The purpose of this warrant is to give adequate gaps in the main traffic stream for school children to cross the road. There must be a minimum of 20 schoolchildren crossing the street during the highest crossing hour so that this warrant is satisfied.

This warrant is not met, as the number of students crossing the intersections (both Daetie and Gebeya) during the maximum crossing hour is less than 20. However, if this intersection is to accommodate student crossing in the future, it is recommended that a gap study on the major street traffic stream be performed prior to a traffic signal warrant study(Maldonado-Burkett Engineers, 2021).

3.3.5. Warrant 6, Coordinated Signal System

No need to check this warrant, as there are no signalized intersection before and after the study intersection. The study intersection is not contained in a coordinated traffic signal system, and does not need to provide a necessary degree of vehicle platooning. As a result, it is determined that Warrant 6 is not met for the study intersection.

3.3.6. Warrant 7, Crash Experience

Checking Crash experience warrant requires a lot of work which beyond the scope of this research. The works required are adequate trail of alternative with satisfactory observance, five or more reported crashes that can be corrected by traffic signal and vehicular volume.

3.3.7. Warrant 8, Roadway Network

No need to check because the intersections are not common to 2 or more major routes.

3.3.8. Warrant 9, Intersection near a Grade Crossing/Railway crossing

No need to check this warrant as there is no grade crossing.

3.4. Signal Design Using Webster Method

3.4.1. Base Saturation Flow Rate

Base saturation flow rate is affected by approaching speed. Approaches with lower approaching speed (less than 50km/h) use 1800pc/h/in and approaches with higher approaching speed use (greater than 80km/h) use higher than 1900pc/h/Ln. (HCM, 2000).

Computations begin with the adjustment of a base saturation flow rate, usually 1,800 passenger cars per hour per lane (pc/h/ln) and adjustment of base saturation flow rate were done for different prevailing conditions. Those adjustments are Number of lanes in the lane group, Adjustment factor for lane width (3.6 m is base condition), Adjustment factor for heavy vehicles in the traffic stream, Adjustment factor for approach grade, Adjustment factor for the existence of parking lane and parking activity adjacent to the lane group, Adjustment factor for blocking effect of local buses that stop within the intersection area, Adjustment factor for area type, Adjustment factor for lane utilization, Adjustment factor for left-turning the lane group, Adjustment factor for right-turning the lane group, Pedestrian adjustment factor for left-turning movements and Pedestrian/bicycle adjustment factor for right-turn movements. Traffic volume study is conducted to determine the number, movements and classifications of roadway vehicles at a given location.

The details of the adjustment factors are indicated in the attached index at end of the report.

Table 8. Adjusted saturation flow rates in Daetie intersection

Time	**From Stadium To Diaspora**											
	Left				**Through**				**Right**			
	2-Wheeler	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**
2:00-2:15	8	7	0	2	34	15	33	2	11	10	0	1
2:15-2:30	7	7	0	1	38	16	35	3	10	9	0	0
2:30-2:45	9	5	0	0	19	9	22	1	9	8	0	0
2:45-3:00	5	7	0	0	14	7	18	0	6	6	0	0
Time	**From Diaspora To Stadium**											
	Left				**Through**				**Right**			
	2-Wheeler	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**
2:00-2:15	26	21	0	5	94	58	67	6	47	35	0	13
2:15-2:30	27	20	0	6	88	55	64	5	45	34	0	11
2:30-2:45	24	19	0	5	77	48	55	4	37	28	0	8
2:45-3:00	21	15	0	3	63	40	46	3	32	21	0	6
Time	**From Gezahegn To Rori**											
	Left				**Through**				**Right**			
	2-Wheeler	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**
2:00-2:15	5	14	0	2	45	80	0	13	8	18	0	2
2:15-2:30	5	12	0	1	42	76	0	12	7	16	0	2
2:30-2:45	4	10	0	1	38	65	0	9	6	15	0	1
2:45-3:00	3	9	0	1	38	56	0	1	5	13	0	1
Time	from Rori to To Gezahegn											
	Left				Through				Right			
	2-Wheeler	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**	**2-Wheeler**	**4-Wheeler**	**3-Wheeler**	**Heavy**
2:00-2:15	18	36	0	5	26	50	0	9	7	17	0	3
2:15-2:30	15	35	0	7	26	48	0	8	6	16	0	3
2:30-2:45	14	34	0	8	25	46	0	8	6	15	0	2
2:45-3:00	16	32	0	6	25	44	0	7	6	16	0	2

The left, right and thorough movements of different vehicle categories (two wheeler, three wheeler, four wheeler and Heavy vehicles) are changed to common passenger car equivalent units (PCU) using PCU conversion values adapted from ERA and Rogers as indicated in the Table 9.

Table 9. Passenger car equivalency (Adapted from ERA manual and Rogers et.al)

Vehicles	**2 - Wheeler**	**4 - Wheeler**	**3 - Wheeler**	**Heavy**
PCU	0.25	1.00	0.40	2.30

In order to design the signal time using the peak hour volume, the vehicular volumes of different vehicle category have to be converted into a passenger car using pcu values. Table below shows the values of equivalent passenger car value for the peak hour volume.

Table 10. Peak hour vehicular volume after the application of PCU

Time	**To Diaspora**			**To Stadium**			**To Rori**			**To Gezahegn**		
	Left	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**	**Left**	**Through**	**Right**
2:00 - 2:15	13.6	41.3	15.1	39.0	122.1	76.7	19.9	121.2	24.6	52.0	77.2	25.7
2:15 - 2:30	11.1	46.4	11.5	40.6	114.1	70.6	15.6	114.1	22.4	54.9	72.9	24.4
2:30 - 2:45	7.3	24.9	10.3	36.5	98.5	55.7	13.3	95.2	18.8	55.9	70.7	21.1
2:45 - 3:00	8.3	17.7	7.5	27.2	81.1	42.8	12.1	67.8	16.6	49.8	66.4	22.1
Total	40.2	130.3	44.3	143.2	415.7	245.7	60.8	398.3	82.3	212.6	287.1	93.3
Total all	**214.7**			**804.6**			**541.3**			**592.9**		

For the adjustment of base flow rate, the determination of percentage of heavy vehicle is mandatory. The Bar chart below indicates the % composition of heavy vehicles moving into the four directions (to Diaspora (EB (East Bound), to Stadium (WB (West Bound), to Rori(SB(South Bound), and to Gezahegn (NB - North Bound)).

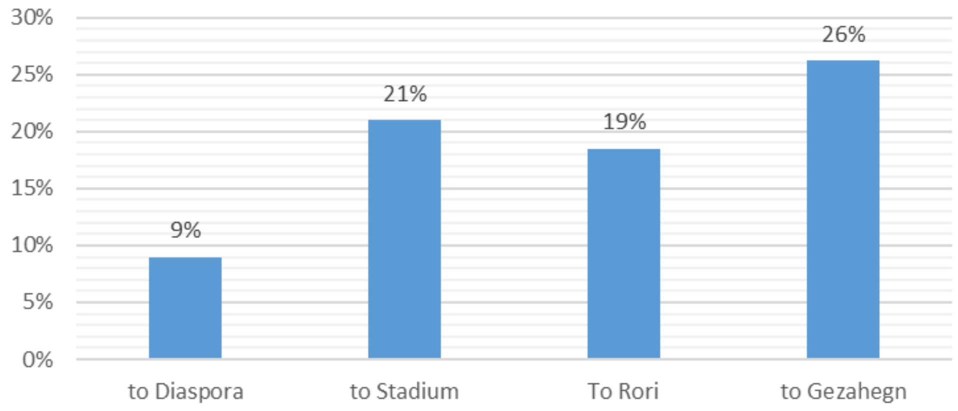

Figure 6. Heavy vehicle composition after adjustment factor

Table 11. Summary of adjusted saturation flow rate and adjustment factor for each bound

Adjustment Factors	**Lane Groups**					
	EB	**WB**	**NB L**	**SB L**	**NB T/R**	**SB T/R**
Base saturation flow (sb, in pc/hg/ln)	1800	1800	1800	1800	1800	1800
Number of lanes (N)	2	2	1	1	2	2
Lane width adjustment (flw)	0.96	0.96	1	1	1	1
Heavy-vehicle adjustment (fhv)	0.999	0.998	0.998	0.997	0.998	0.997
Grade adjustment (fg)	1	1	1	1	1	1
Parking adjustment (fp)	1	1	1	1	1	1
Bus blockage adjustment (fbb)	1	1	1	1	1	1
Area type adjustment fa	1	1	1	1	1	1
Lane utilization adjustment (fLU)	1	1	1	1	1	1
Left-turn adjustment (fLT)	0.95	0.95	0.95	0.95	0.95	0.95
Right-turn adjustment (fRJ)	0.85	0.85	1.00	1.00	0.85	0.85
Left-turn pedestrian-bicycle adjustment (fltpb)	1	1	1	1	1	1
Right-turn pedestrian-bicycle adjustment (fRpb)	1	1	1	1	1	1
Adjusted saturation flow (s, in veh/hg/ln)	2795.2	2791.9	1710.7	1709.8	2900.9	2890.8

Webster has shown that for a wide range of practical conditions minimum intersection delay is obtained when the cycle length is obtained by the equation

The total lost time for the cycle will also be used in the calculation of cycle length. In determining the total lost time for the cycle, the general rule is to apply the lost time for a critical lane group when its movements are initiated (the start of its green interval) (Fred and Scott, 2013).

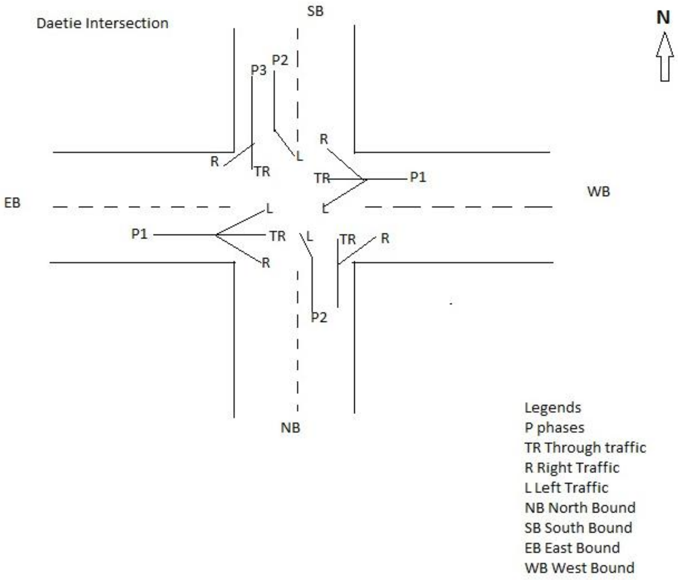

Figure 7. Phase movements in Daetie intersection

The critical design hourly volume of each lane estimated in the table 11 for the four phases. The first phase allows movement of traffic in east bound (Stadium approach) in Right, Through and left direction while the second phase allows movement of traffic in west bound in right, through and left direction. In the third phase movement of left movement form north and south bound are entertained and for the last phase movement of through and right turning traffic in north and south approach allowed.

Table 12. Number of lanes, lane groups and analysis flow rate to determine critical lane

Number of Lane	**Phases**	**Lane Groups**	**Saturation Flow Rate**	**Analysis Flow Rate**	**yi=qi/Si**	**ycr**
1	Phase 1	EB :	2795.2	217	0.078	0.078
1	Phase 2	WB :	2791.9	805	0.288	0.288
1	Phase 3	NB L:	1710.7	61	0.036	0.125
1		SB L:	1709.8	213	0.125	
2	Phase 4	NB T/R:	2900.9	482	0.166	0.166
2		SB T/R:	2890.8	382	0.132	
					Y =	**0.657**

The summation of critical Y (demand volume to saturation flow rate) is used to estimate optimum signal time and the green time for each lane group using the formula shown in table 12.

Table 13. Green time for each lane group

Total lost time per cycle (L) = 2n+R	13
Optimum Signal Time, $C_o = (1.5L+5)/(1-Y)$	71.37
Green time for Lane Group 1 (G_1) = (y_1/Y)*(Co-L)	6.90
Green time for Lane Group 2 (G_1) = (y_1/Y)*(Co-L)	25.63
Green time for Lane Group 3 (G_2) = (y_2/Y)*(Co-L)	11.07
Green time for Lane Group 4 (G_3) = (y_3/Y)*(Co-L)	14.77

n = 4 phases, R = 5 seconds (All red time)

Table above shows calculated green times for each phase using optimum cycle time of 71.37 seconds. According to Martin (2003), the minimum cycle time suggested is 25 seconds based on safety considerations and a maximum cycle time of 120 seconds is considered for good practice. Normally the cycle time will lie within the range of 30 to 90 seconds and if we fix the optimum time at 90 seconds the green time, the amber time and the red time for each lane groups are as indicated in the 13 table.

Table 14. Green time allocation for each lane group using 90 seconds of cycle length

Time	**Phase - 1**	**Phase - 2**	**Phase - 3**	**Phase - 4**
Green	10	35	15	20
Amber	3	3	3	3
Red	72	47	67	62
All Red	5	5	5	5

The total cycle time before the traffic update was 120 seconds which is more than the updated which is 90 seconds. This cycle is divided into four phases: phase 1 is East bound and West bound through movements, phase 2 is East bound and West bound left turns,phase 3 is North and South bound through movements and phase 4 is North and South bound left turns.

Table 15. Existing Signal time for Daetie intersection using 120 seconds

Time	**Phase - 1**	**Phase - 2**	**Phase - 3**	**Phase - 4**
Green	30	20	30	20
Amber	3	3	3	3
Red	80	90	80	90
All Red	5	5	5	5

The green times dedicated for all phases is similar for most of the periods is 30 seconds which does not accound the varied traffic environment. For example the vehicular traffic and the heavy vehicular composition on the main road is higher than the minor road that assures the higher demand for green time. This itself indicates there should be an update for traffic signal timing based on current traffic count.

4. Conclusion

The total vehicular traffic count for Gebeya intersection is 18160 vehicles, the total vehicular traffic count for Daetie intersection is 25242 vehicles. The warrant analysis indicates that both the **Daetie** and **Aroge Gebeya** intersections satisfy the key MUTCD criteria for signalization, specifically the **8-hour**, **4-hour**, **peak-hour**, and **pedestrian volume** warrants.

These findings confirm that traffic volumes and pedestrian activity at both locations are sufficiently high to justify traffic signal control. The **school crossing** warrant was not met due to the limited number of students crossing the roadway, while the **coordinated signal system**, **roadway network**, and **grade crossing** warrants were deemed not applicable given the geometric and operational characteristics of the study area.

Crash data were not evaluated within the scope of this study. Overall, the results affirm that both intersections meet multiple warrants supporting the implementation or continuation of signalized control, ensuring safer and more efficient traffic operations. The optimum cycle time of 71.37 seconds is found using Webster Method of signal design. The comparison between current traffic signal time and existing time indicates there should be an update for signal time based on current traffic count.

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Competing Interests

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