Analysis of the Effect of Vehicle Composition at Signalized Intersections on the Initial Loss Time of the Green Phase

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Abstract— Cycle time consists of green time, yellow time, and red time. The green time of a phase is a function of the effective green time as well as the initial loss time and final gain time. There needs to be an approach to determine the value of the initial loss time at signalized intersections. There are several aspects that influence this, one of these aspects is the composition of vehicles at the intersection, this is because each vehicle has different acceleration variations in reaching normal speed conditions after stopping at the intersection. Analysis was carried out by observing video of traffic conditions at the Jl. Demak – Jl. Dupak, Surabaya on every approach. Observations were made on group vehicle behind line stop 12 m back until the group of vehicles exits the approach during the green phase, so that data on the composition of the vehicle group and the initial loss time that occurs for each green phase are obtained. The results of the analysis of the influence of vehicle composition on initial loss time using the vehicle group acceleration approach show that the initial loss time range that can occur is between 8.5 seconds to 14 seconds which is influenced by acceleration vehicle group.

Keywords— vehicle composition, signalized intersection, initial loss time.

I. INTRODUCTION

A. BACKGROUND

The city of Surabaya is the second largest metropolitan city in Indonesia and is also the capital of East Java Province. Rapid progress in recent years in various sectors of activity such as the economy, education and the environment has resulted in an increasing population of the city of Surabaya. This has not been balanced by the increase in transportation facilities such as roads in Surabaya, resulting in an increasingly high level of traffic congestion. We can see that one aspect of traffic congestion is the long buildup of vehicles during the red phase at signalized traffic intersections.

The accumulation of vehicles at signalized intersections is also influenced by the lack of precise planning and regulation of the signalized intersection system. As base in planning and arrangement at this signalized intersection, Indonesia has a guideline regarding Indonesian highways called the Indonesian Road Capacity Manual (MKJI), where the manual comes from an international highway guidebook which was then adopted, some of which have been adapted to the characteristics of vehicles and roads in Indonesia.

One part of the Indonesian Road Capacity Manual that has not yet been adapted to the characteristics of Indonesian traffic is regarding the determination of the initial loss time and final additional time at a green phase of a signalized intersection. The manual explains that these two phenomena are assumed to have the same time span so that it can be immediately concluded that the green display time will be the same as the effective green time. However, research needs to be carried out to find out the exact characteristics of the phenomenon of initial loss time and final additional time, so that a more realistic and appropriate approach can be made in planning cycle times at signalized intersections, both from red time, yellow time, red time. all, effective green time, early loss time, and late extra time.

The initial loss time is the time required for the vehicle to start moving from rest at the start of the green time. Several factors that influence the initial loss time are differences in the acceleration of motor vehicles for each type, whether motorbikes, cars, or trucks (Arpan Mehar et al, 2013) [1]. Apart from that, it is also influenced by the level of vehicle composition at the intersection (Puspita Deo and Heather J. Ruskin, 2014) [2]. However, further analysis needs to be carried out regarding this relationship with the characteristics of intersections in Indonesia. Seeing this, this analysis tries to find a relationship between vehicle composition and initial loss time in the green phase of signalized intersections based on traffic conditions in Indonesia in general and in Surabaya in particular. The analysis will be carried out by taking data on the existing flow conditions at the Jalan Demak-Jalan Dupak intersection, Surabaya.

B. PROBLEM FORMULATION

Some of the problems that will be discussed in this final assignment include:

1. What is the composition of vehicles and initial loss time per cycle time at each approach based on the existing conditions of the intersection?
2. How does vehicle acceleration and vehicle composition influence the initial loss time at an intersection?

C. OBJECTIVE

The objectives to be achieved in preparing this final assignment are:

1. Knowing the characteristics of vehicle composition and initial loss time per cycle time at each intersection approach.
2. Knowing the influence of vehicle acceleration and vehicle composition on the initial loss time at an intersection

D. PROBLEM LIMITS

So that when writing this final assignment there are no

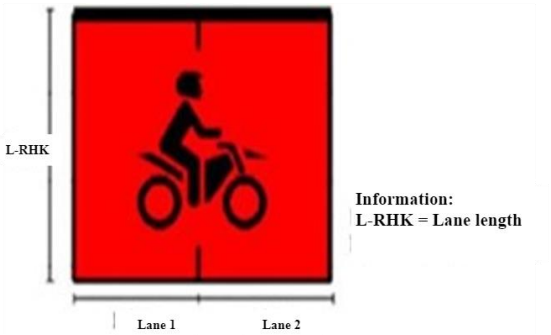

Fig 1. Box type RHK

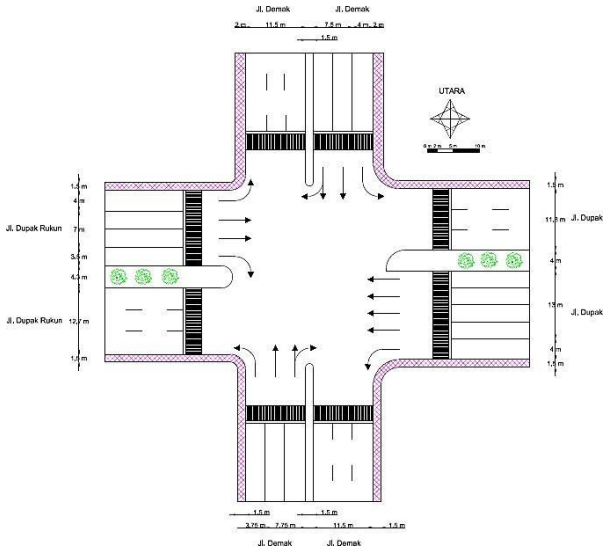

Fig 2. Illustration of the Observation Area at the Jl. Demak – Jl. Dupak, Surabaya

deviations in discussing the problem, it is necessary to define the problem as follows:

1. This analysis only reviews the Jalan Demak intersection Dupak street, Surabaya with its existing condition.
2. This analysis uses existing traffic light settings.
3. This analysis is carried out based on vehicle composition data in the area approaching existing oncoming vehicles which are behind the stop line.
4. Analysis of vehicle composition and initial loss time only in the approach lane with straight movements and right turns.
5. This analysis does not focus on vehicle volume, but rather on the composition of existing vehicles.
6. Do not pay attention to the influence of the vehicle's carrying load.
7. Do not pay attention to the influence of the width of the approach lane.

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TABLE 1.

RHK Capacity of 2 Lane Box Type

RHK Lane Length (L-RHK)	Area (m2)			Maximum Motorcycle Capacity
	Lane1	Lane2	Total	
8	28	28	56	37
10	35	35	70	46
12	42	42	84	56

TABLE 2.

Average Vehicle Composition North Approach

Time	Approach		Amount	Average Vehicle Composition (%)		
Observation	Direction	Width (m)	Data	MC	LV	H.V
06.30-07.30	North	7,5	14	54%	43%	4%
13.00-14.00			13	47%	40%	13%
14.00-15.00			8	63%	35%	2%
16.00-17.00			11	50%	43%	7%

8. The initial loss time in this analysis refers to the time required for a vehicle during the green phase, from stopping in the observation area to reaching normal speed after leaving the observation area on the existing road section.
9. Vehicle composition analysis only pays attention to the number of vehicles in the observation area without paying attention to the position configuration of the vehicles.
10. The approximate calculation of vehicle group acceleration values is only used as a connecting variable between the influence of vehicle composition on the initial loss time that occurs.

II. METHODOLOGY

The systematic research methodology is as follows:

1. Phase I consists of introduction, literature study, problem formulation, location selection, and data collection.
2. Phase II, consists of two parts, namely:
   a. Analysis of vehicle composition and initial loss time at intersections.
   b. Analysis of the influence of acceleration and vehicle composition on initial loss time at intersections.
3. Stage III is writing up the study results.

III. RESULTS AND DISCUSSION

A. ANALYSIS OF INITIAL LOSS TIME AND VEHICLE COMPOSITION

This analysis aims to determine the characteristics of initial loss time and vehicle composition at intersections based on existing field data. Observations of vehicle composition values and initial loss times were carried out based on video data from intersection traffic on Jl. Demak – Jl. Dupak, Surabaya. These observations were made at the start of each green time at each approach with a total video duration of 180 minutes.

The observation area used consists of the width of each approach as follows:

a) North : 7.50 m (straight movement and right turn)
b) South: 7.75 m (straight movement and right turn)

TABLE 3.

Average Vehicle Composition South Approach

Time	Approach		Amount	Average Vehicle Composition (%)		
Observation	Direction	Width (m)	Data	MC	LV	H.V
06.30-07.30	South	7,75	14	67%	33%	0%
13.00-14.00			12	35%	63%	2%
14.00-15.00			6	45%	52%	3%
16.00-17.00			12	49%	51%	0%

TABLE 4.

Average Vehicle Composition West Approach

Time	Approach		Amount	Average Vehicle Composition (%)		
Observation	Direction	Width (m)	Data	MC	LV	H.V
06.30-07.30	West	7	15	25%	70%	5%
13.00-14.00			15	22%	73%	5%
14.00-15.00			8	20%	74%	7%
16.00-17.00			12	29%	64%	6%

TABLE 5.

Average Vehicle Composition East Approach

Time	Approach		Amount	Average Vehicle Composition (%)		
Observation	Direction	Width (m)	Data	MC	LV	H.V
06.30-07.30	East	13	15	35%	64%	2%
13.00-14.00			14	25%	71%	4%
14.00-15.00			8	24%	69%	7%
16.00-17.00			12	29%	68%	3%

c) West : 7.00 m (straight motion)

d) East : 13.0 m (straight motion)

As well as determining the length of the observation area, considering that the acceleration of the initial line of vehicles has the greatest influence on the initial loss time that occurs at the beginning of the green phase of an approach. This is in accordance with the planned lane length recommended in the planning of Special Stopping Spaces (RHK) for motorbikes by the Ministry of Public Works which can be seen in table 1 and figure 1. So, we get the observation area presented in Figure 2.

The results of observing the composition of vehicles in the green phase at each approach and the time of video observation of traffic at the Jl. Demak – Jl. Dupak, Surabaya which have been converted into passenger cars are presented in tables 2 to 5. Meanwhile, the results of observations of the initial loss time are presented in table 6.

B. ANALYSIS OF THE EFFECT OF ACCELERATION AND VEHICLE COMPOSITION ON INITIAL LOSS TIME

This analysis aims to determine the acceleration of each type of vehicle and the influence of this acceleration and the composition of the vehicle on the initial loss time that occurs.

Observation of vehicle acceleration is carried out at the length of the viewing distance for each approach taken from the approach stop line to the median axle of the road from the approach to the left of the approach, the length of the viewing distance for each approach is as follows:

a) North Approach = 24.8 m
b) South Approach= 28.15 m
c) West Approach = 24.26 m
d) East Approach = 27.25 m

TABLE 6.

Average Initial Loss Time for All Approaches

Direction Approach	Amount Data	Average Vehicle Composition (%)			Lost Time Initial average(seconds)
		MC	LV	H.V	
Observation Time 06.30-07.30					
North	14	54%	43%	4%	9,29
South	14	67%	33%	0%	9,50
West	15	25%	70%	5%	10,27
East	15	35%	64%	2%	7,33
Observation Time 13.00-14.00					
North	13	47%	40%	13%	9,31
South	12	35%	63%	2%	9,67
West	15	22%	73%	5%	9,33
East	14	25%	71%	4%	7,93
Observation Time 14.00-15.00					
North	8	63%	35%	2%	10,00
South	6	45%	52%	3%	7,83
West	8	20%	74%	7%	9,00
East	8	24%	69%	7%	8,63
Observation Time 16.00-17.00					
North	11	50%	43%	7%	10,09
South	12	49%	51%	0%	10,08
West	12	29%	64%	6%	9,83
East	12	29%	68%	3%	9,83

TABLE 7.

Observations of Acceleration for Each Type of Vehicle

Acceleration	MC			LV			H.V		
Vehicle	Amount	Percentage	Cumulative	Amount	Percentage	Cumulative	Amount	Percentage	Cumulative
(m/s²)	(Unit)	%	%	(Unit)	%	%	(Unit)	%	%
0,23-0,52	0	0,0%	0,0%	28	6,0%	6,0%	21	45,7%	45,7%
0,53-0,82	69	6,1%	6,1%	149	31,7%	37,7%	17	37,0%	82,6%
0,83-1,12	281	24,8%	30,8%	186	39,6%	77,2%	7	15,2%	97,8%
1,13-1,42	296	26,1%	56,9%	59	12,6%	89,8%	1	2,2%	100,0%
1,43-1,72	196	17,3%	74,2%	26	5,5%	95,3%	0	0,0%	100,0%
1,73-2,02	137	12,1%	86,3%	13	2,8%	98,1%	0	0,0%	100,0%
2,03-2,32	104	9,2%	95,4%	8	1,7%	99,8%	0	0,0%	100,0%
2,33-2,62	0	0,0%	95,4%	0	0,0%	99,8%	0	0,0%	100,0%
2,63-2,92	0	0,0%	95,4%	0	0,0%	99,8%	0	0,0%	100,0%
2,93-3,22	37	3,3%	98,7%	1	0,2%	100,0%	0	0,0%	100,0%
3,23-3,52	15	1,3%	100,0%	0	0,0%	100,0%	0	0,0%	100,0%

TABLE 8.

Average Acceleration of Each Type of Vehicle

Vehicle Acceleration				
Type	sample	min	max	mean
Vehicle	vehicle	(m/s²)	(m/s²)	(m/s²)
MC	1135	0,56	3,52	1,48
LV	470	0,28	3,03	0,97
H.V	46	0,25	1,35	0,60

The results of observing vehicle acceleration are presented in tables 7 and 8.

Next, an analysis of the influence of vehicle composition on vehicle acceleration and actual initial loss time is carried out with the results presented in figure 6 to 13.

From figures 8 to 13 the R value2 less than 0.5 which is a requirement for the consistency of a pattern. This is because the data variations are quite large. Based on the function of the

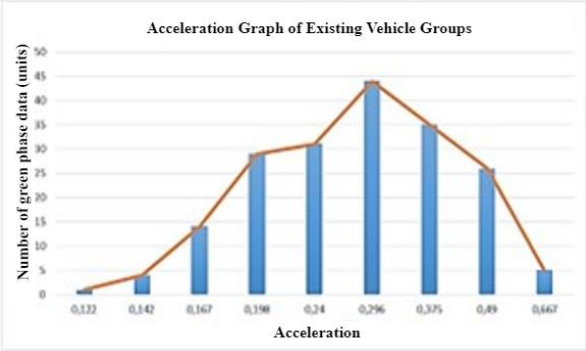

Fig 3. Acceleration Graph of Existing Vehicle Groups

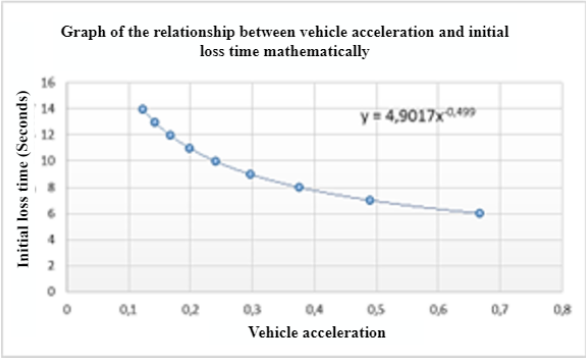

Fig 4. Graph of the relationship between vehicle acceleration and initial loss time mathematically

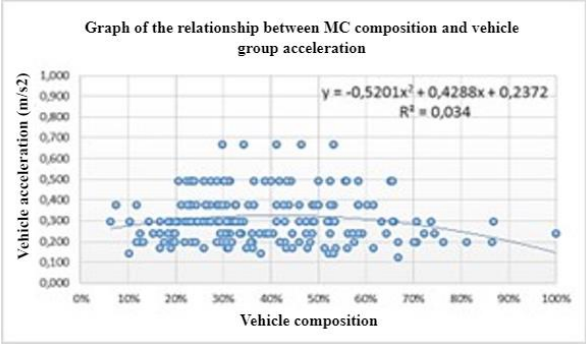

Fig 5. Graph of the relationship between MC composition and vehicle group acceleration

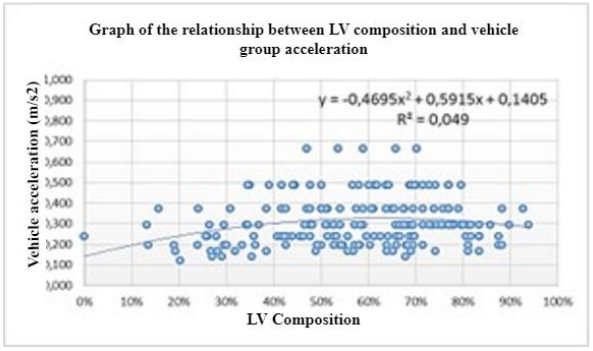

Fig 6. Graph of the relationship between LV composition and vehicle group acceleration

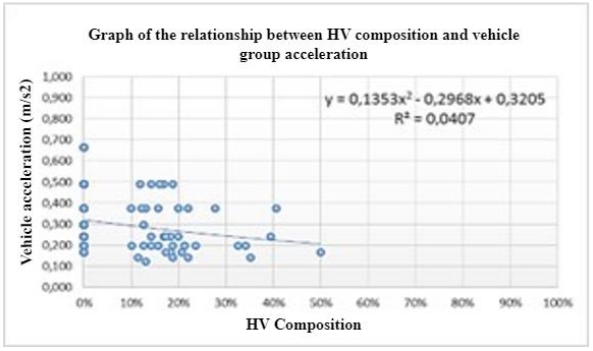

Fig 7. Graph of the relationship between HV composition and vehicle group acceleration

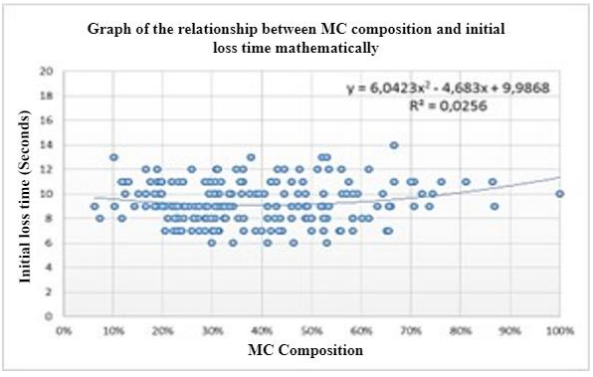

Fig 8. Graph of the relationship between MC composition and initial loss time mathematically

acceleration pattern, it shows values close to the optimum vehicle composition for each type, when the MC composition is 41%, LV 63%, and HV 0%. Meanwhile, the initial loss time pattern function shows values close to the optimum vehicle composition for each type, when the MC composition is 39%, LV 68%, and HV 0%.

Next, the initial loss time and acceleration of the vehicle group can be calculated using formulations 3.1 and 3.2.

$Wl_{flat} = Wl_{MC} \times \%MC + Wl_{LV} \times \%LV + Wl_{H.V} \times \%HV$

Where:

Wl_{flat} = Group Initial Loss Time (seconds) Wl_{MC} = MC Initial Loss Time (seconds)

%MC = MC Vehicle Composition (%)

$a_{flat} = a_{MC} \times \%MC + a_{LV} \times \%LV + a_{H.V} \times \%HV$

Where:

a_{flat} = Vehicle Group Acceleration (m/s^2)

a_{MC} = MC acceleration (m/s^2)

%MC = MC Vehicle Composition (%)

An analysis of the relationship between the average acceleration of each type of vehicle and the acceleration of vehicles when grouped was carried out. This aims to simplify the application of the relationship between vehicle composition and vehicle acceleration. The approach to the acceleration coefficient value is as follows:

$The_{MC} = a_{MC} / a_{rata\text{-}rataMC}$

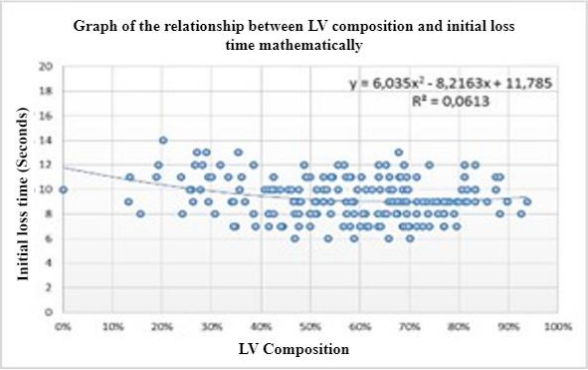

Fig 9. Graph of the relationship between LV composition and initial loss time mathematically

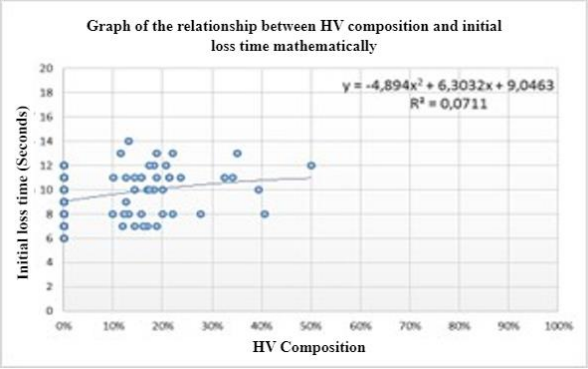

Fig 10. Graph of the relationship between HV composition and initial loss time mathematically

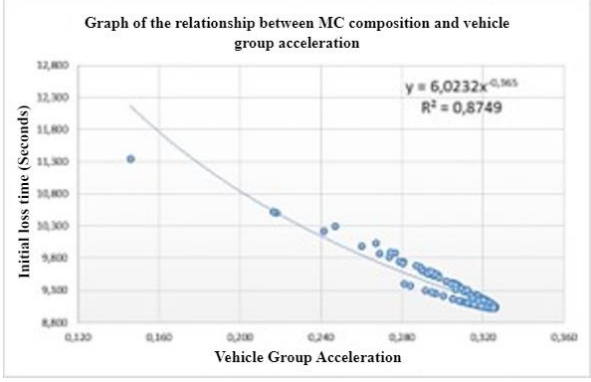

Fig 11. Graph of the relationship between vehicle group acceleration and initial loss time

TABLE 9.

Average Acceleration of Each Type of Vehicle

Type Vehicle	Average Acceleration (m/s2)
MC	1,48
LV	0,97
H.V	0,6

TABLE 10.

Vehicle Acceleration Coefficient

Vehicle Acceleration Coefficient			
Composition	MC	LV	H.V
1%-20%	0,19	0,20	0,49
21%-40%	0,21	0,28	0,41
41%-60%	0,22	0,33	0,34
61%-80%	0,19	0,33	0,30
81%-100%	0,13	0,30	0,27

TABLE 11.

Acceleration and Initial Loss Time

Approach	North		Acceleration	Lost Time
Vehicle Composition			Kendaraan (m/s²)	Initial (seconds)
MC	LV	H.V	TOTAL	TOTAL
Observation Time 06.30-07.30				
50%	50%	0%	0,320	9,171
49%	51%	0%	0,321	9,149
53%	47%	0%	0,317	9,230
36%	64%	0%	0,326	9,030
54%	28%	18%	0,296	9,570
56%	27%	17%	0,294	9,590
57%	43%	0%	0,310	9,329
52%	48%	0%	0,317	9,215
53%	47%	0%	0,317	9,230
52%	48%	0%	0,317	9,215
60%	24%	16%	0,290	9,637
64%	36%	0%	0,296	9,526
59%	41%	0%	0,307	9,375
56%	44%	0%	0,313	9,284

(3.3)

Where:

The_{MC} = Vehicle Acceleration Coefficient

aMC = MC acceleration (m/s²)

$a_{rata\text{-}rataMC}$ = Average Acceleration MC (m/s²)

So the results of the acceleration coefficient analysis are obtained which are presented in tables 3.9 and 3.10 as well as the new formulation in 3.4.

aflat= arataMCx %MC x KaMC + arataLVx %LV x KaLV + a_{RataHV} x %HV x $Ka_{H.V}$ *(3.4)*

Where:

aflat = Vehicle Group Acceleration (m/s²) a_{rataMC} = Average Acceleration MC (m/s²)

%MC = MC Composition (%)

The_{MC} = Acceleration Coefficient MC

Based on the results of this analysis, a relationship was obtained between the influence of acceleration and vehicle composition on the initial loss time. In table 3.11, a recapitulation of calculations on the northern approach with an observation time of 06.30-07.30 is presented, and in figure 3.14,

a graph of the relationship between vehicle group acceleration and initial loss time from all data of 189 green phases with a standard deviation of 0.115 is presented.

IV. CONCLUSION

1. Conclusion

Based on the results of the analysis of the influence of vehicle composition at signalized intersections on the initial loss time of the green phase that has been carried out, the following conclusions can be drawn:

a) The initial loss time occurs between 6-14 seconds which is influenced by the composition of the vehicle at each approach. The composition of MC type vehicles in observations ranged from 20%-67%, while for LV type vehicles it was between 33%-74%, and for HV vehicles between 0%-13%.
b) The average acceleration of each type of vehicle observed for MC type vehicles is 1.48 m/s2, the type of vehicle LV 0,97 m/s2, while the type of vehicles HV 0.60 m/s2. In addition, each type of vehicle has a pattern regarding the acceleration of the vehicle group and the initial loss time that occurs. The acceleration pattern of this group of vehicles reduces the average acceleration of each type of vehicle, for the MC type it is reduced to 13%-22% of the average acceleration, for the LV type it is 20%-33%, while for the HV type it is 27%-49%. Modeling the influence of vehicle composition on initial loss time shows an initial loss time range of between 8.5 seconds to 14 seconds.

2. Suggestion

Suggestions that can be given based on the results of the analysis in this Final Project include:

a) The analysis that has been carried out only looks at the relationship between a type of vehicle, so a simultaneous analysis is needed to look at the traffic composition using a 3D Matlab model which will produce values that are close to real conditions and can provide the composition of existing vehicles.
b) Further studies need to be carried out regarding the influence of the composition of each vehicle at signalized intersections on the initial loss time of the green phase which is carried out at more study intersection locations with 3D Matlab.
c) Further analysis needs to be carried out regarding the influence of approach width and vehicle load on average acceleration based on vehicle composition using 3D Matlab.
d) Further analysis needs to be carried out regarding the simulation of the application of intersection cycle timing based on the influence of vehicle composition on the initial loss of time, on existing traffic behavior.

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