CHAPTER 4. DATA COLLECTION AND ANALYSIS

Data collection is an essential part of problem identification process and of contributing to system design as well. Three main factors play major a role in shaping the outcome of the analysis. So we need to collect data that characterize those attributes, which are:

1- Road attributes: Road layout, cross section, vertical profile, and abutting land use, etc.

2- Traffic attributes: traffic volumes, classification, and speed.

3- Accidents attributes: accidents history and violations characteristics.

4.1 Road Attributes

4.1.1 Road Inventory

A field survey was conducted along the stretch of the road under study where measurements were taken for road length associated with cross section elements such as the number of lanes, pavement and shoulders width, driveways and utilities (electric poles) locations. Figure 4-1 shows an overview of the road stretch plan.

The stretch is about 2100 feet long and has an 80 feet right-of-way. The pavement width is about 29 feet. It extends over two 12-ft wide lanes with 2 feet paved shoulders along the westbound lane and 3 feet along the eastbound lane. Unpaved shoulder has a variable width and ranges from nil to 3 feet.

4.1.2 Vertical profile of the site

The geometric layout and vertical profiles are taken from original hand-drafted plans and profiles provided by VDOT. Plan # A 2287-9, shown in figure 4-1, illustrates the road plan and profile. Accordingly, the vertical curve of the hill, starts at mile point 116, almost at Rolling Hills bifurcation, and ends at mile point 137 where the pavement at those two points are level tangent.

As depicted in Figure 4-2, the eastern side (Christiansburg) of the vertical curve of the hill, the grade increases up to 4.2% over a length of 325 feet. The tangent at that endpoint of the upgrade curve falls at mile point 119.25. This point represents the overturning point of the S curve where the vertical curve continues with a decreasing grade.

On the other western side (Radford) of the curve, the length of the straight slope is 4.2% steep and 425 ft long (1 inch on plans = 100 feet horizontally and 10 feet vertically). It starts at mile point 127.75, and ends at mile point 132 (425 feet) where it connects to a curve with decreasing grade extending over 500 feet till mile point 137.

The 4.2% slopes on both sides of the hill are connected by a parabolic curve with a horizontal length of 850 ft. Vertical curve's crest top is located at mile point 123.75.

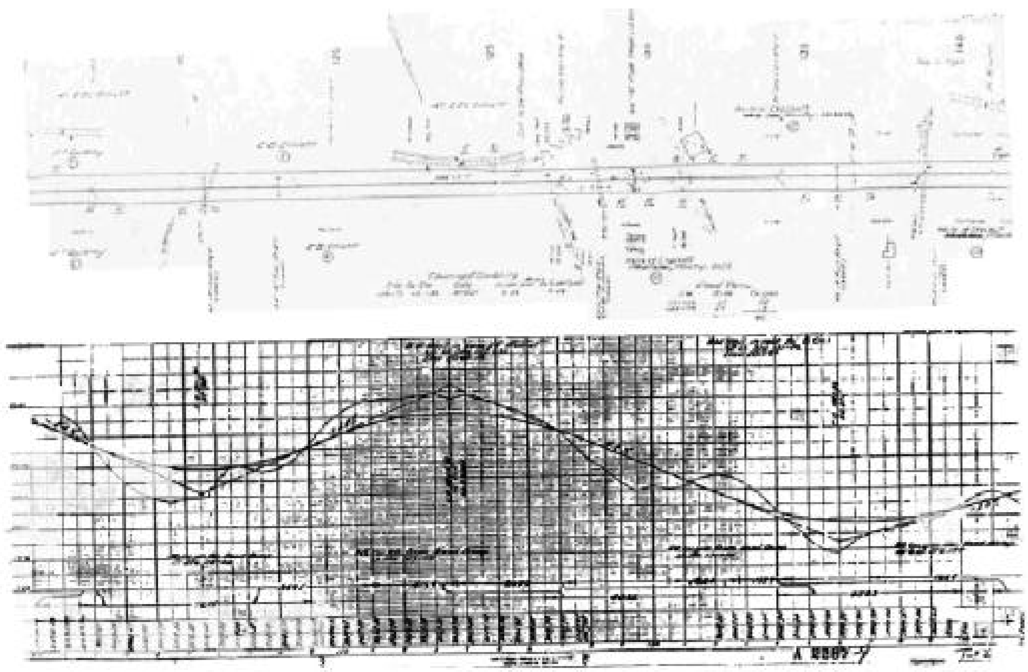


Figure 4-1. Original Plan Road layout and Profile

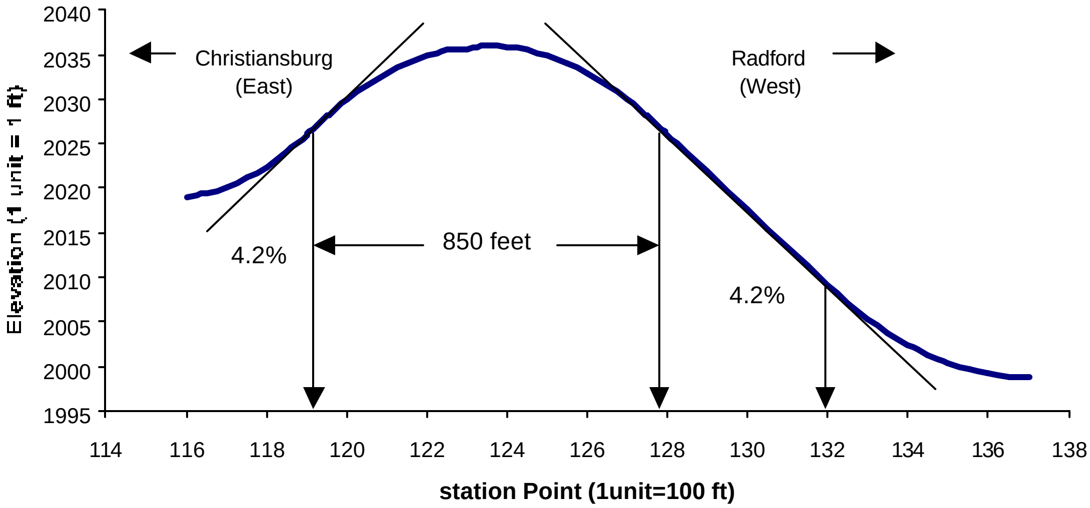


Figure 4-2. Site Vertical Curve

4.2 Traffic characteristics

The objective of conducting traffic surveys is to collect necessary data about the characteristics of some traffic parameters that would affect the safety analysis, such as violation rates, vehicle types and the speed. Therefore, VDOT installed two machine counters - one in each direction - at project site between the 14th and the 27th of September 2000. The counters were programmed to perform speed distribution by vehicle type for 15- minute periods from which we have extracted results for the following three types of traffic surveys:

4.2.1Traffic volume

Traffic volume plays a major role in associating violation rates and in determining arrival rate for simulation purposes. Tables A4-1a to A4-1g in the Appendix present the hour count and distribution of traffic by day and by direction for two weeks, starting from Thursday September 14 till Wednesday 27 inclusive. Every table is associated with one or two charts (see figures 4-3a to 4-3k) showing flow variation for full day directional count (some data were missed due to hose failure) for the sake of comparing between the directional traffic volumes for the same day in the two-week count. The charts revealed that the directional traffic patterns at the same day of the week look quite identical, reflecting the stable commuting characteristics between Radford and the commercial and business area located on route 460 serving the three major towns of Montgomery County.

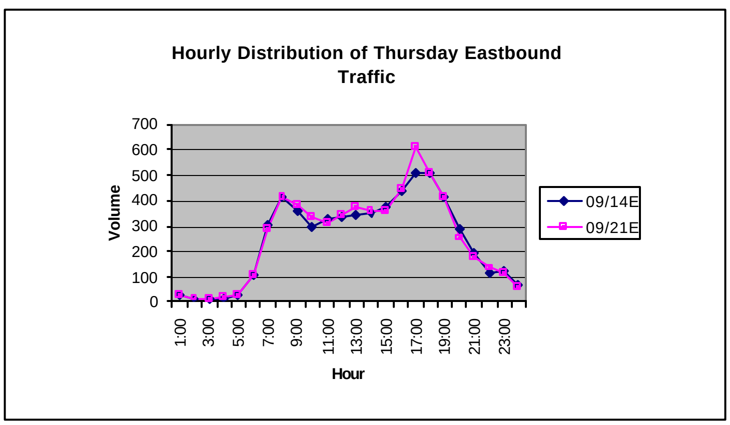


Figure 4-3a: Thursdays Traffic Distribution (East)

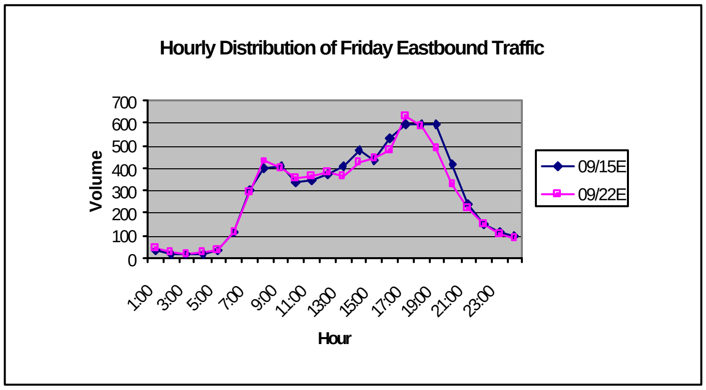
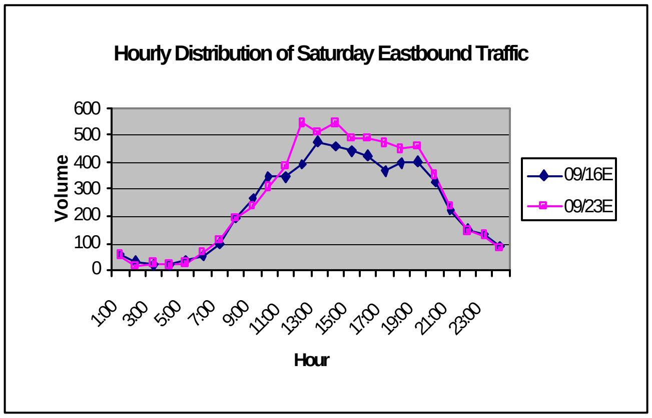


Figure 4-3b: Fridays Traffic Distribution (East)



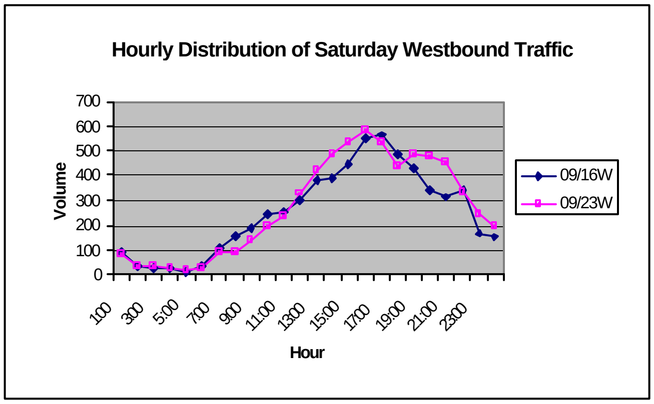
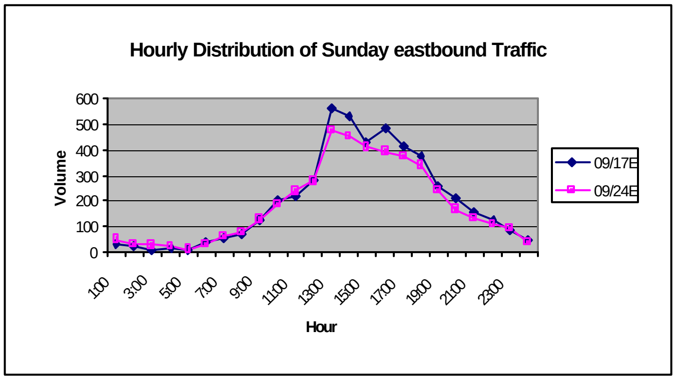


Figure 4-3c&d: Saturdays Traffic Distribution (East & West)



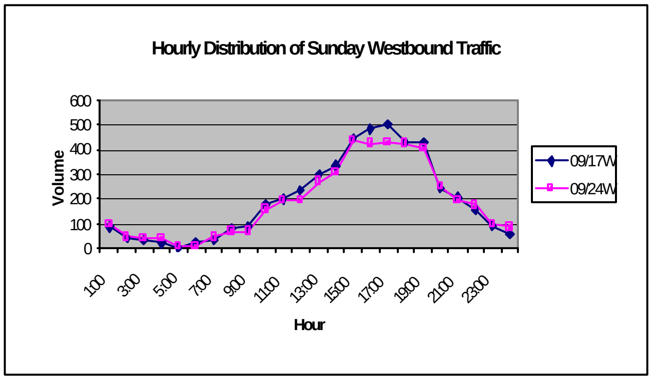


Figure 4-3e&f: Sundays Traffic Distribution (East & West)

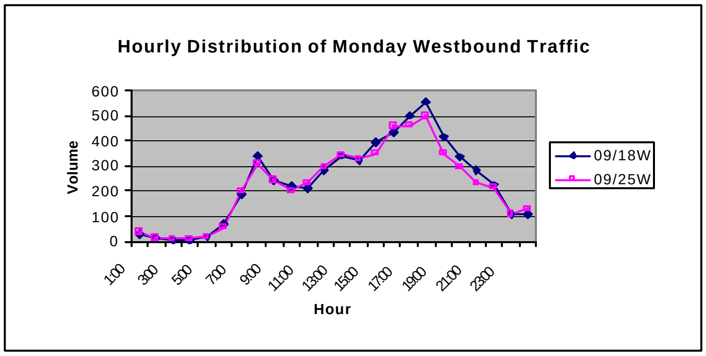


Figure 4-3g: Mondays Traffic Distribution (West)

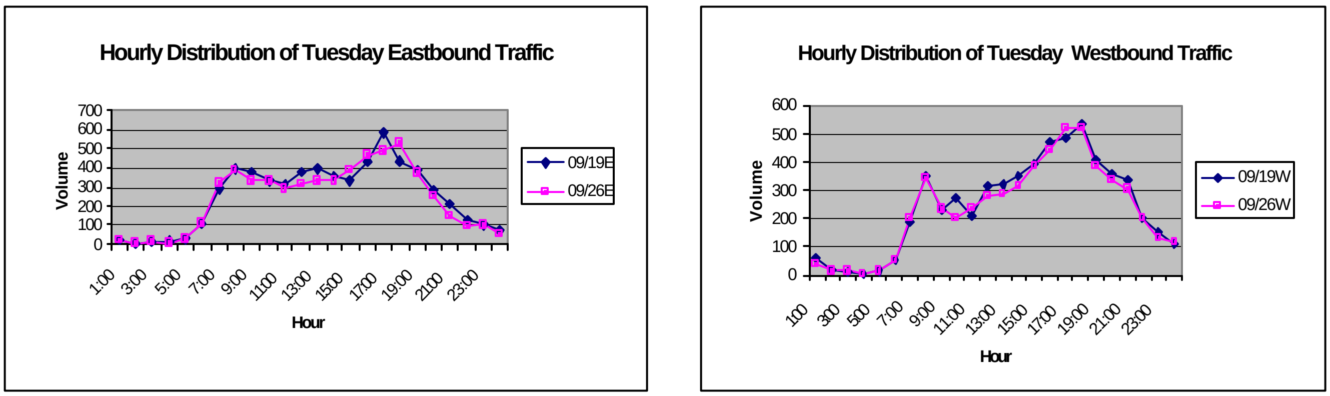


Figure 4-3h&i: Tuesdays Traffic Distribution (East & West)

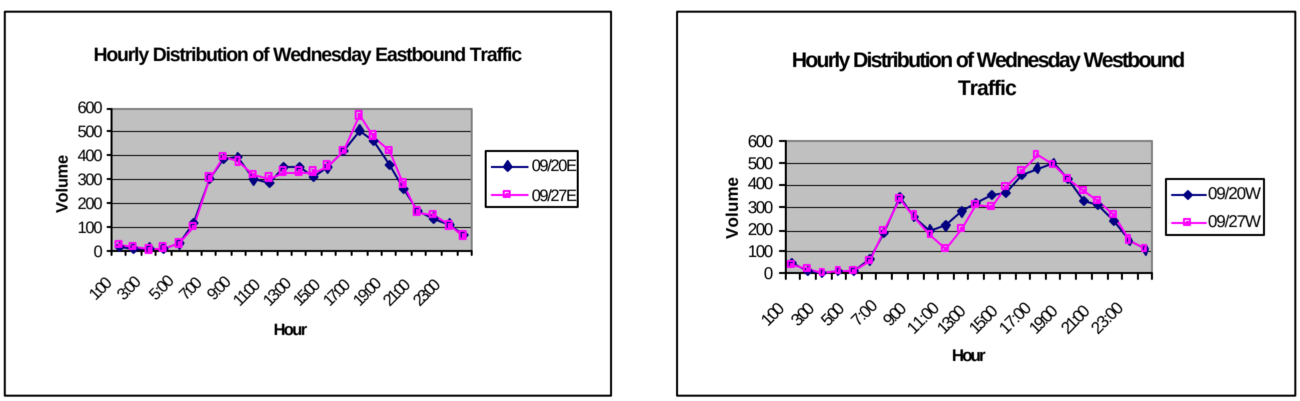


Figure 4-3j&k: Wednesdays Traffic Distribution (East & West)

Also, we may notice from the charts that hourly volumes are also close to one another, with total daily variations ranging from – 4.6 % to +2.2 % for weekdays, and from – 7.6 % to +10.1% for weekend (probably because of some events such as the football games).

Table 4-1 summarizes the daily directional volumes. At average daily level the combined variation of traffic observed is almost none for eastbound direction, about 1% in westbound direction, and 0.5% for both directions.

Table 4-1: Daily Traffic Summary

	Week 1			Week 2			Average Week		
Day	**East**	**West**	**Bi-directional**	**East**	**West**	**Bi-directional**	**East**	**West**	**Bi-directional**
Monday	5801	5639	11440	I	5393	I	5801	5516	11317
Tuesday	5988	5713	11701	5865	5607	11472	5927	5660	11587
Wednesday	5755	5884	11639	5684	5628	11312	5720	5756	11476
Thursday	5963	5849	11812	6097	I	I	6030	5849	11879
Friday	7018	I	I	6768	6535	13303	6893	6535	13428
Saturday	5749	6330	12079	6044	6490	12534	5897	6410	12307
Sunday	4752	4391	9143	4722	4502	9224	4737	4447	9184
Average daily	**5861**	**5634**	**11495**	**5863**	**5693**	**11556**	**5858**	**5739**	**11597**
Variation				**0.04%**	**1.03%**	**0.53%**			

N.B.: I denotes incomplete count

The daily traffic based on an average week is shown in Figure 4-4, where the four weekdays Mondays through Thursdays (regular workdays) and Saturdays (shopping day) conserve a stable flow very close to the ADT calculated.

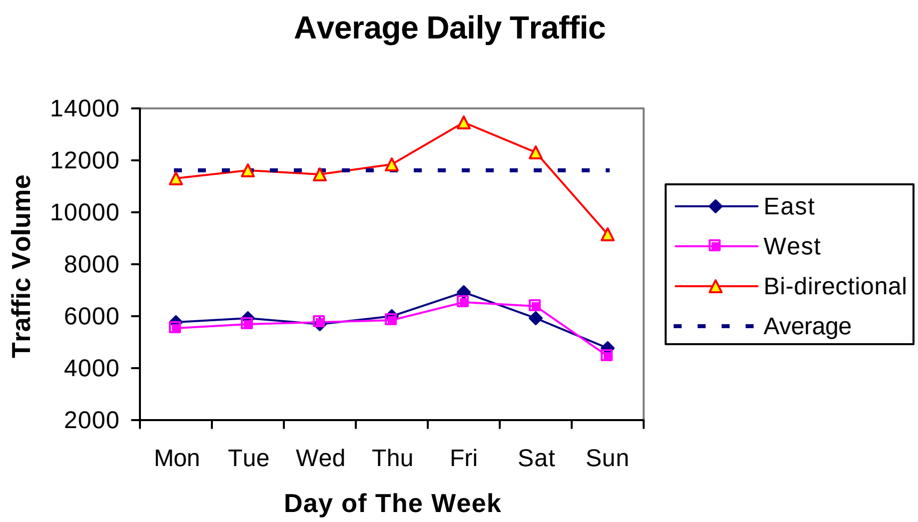


Figure 4-4: Average Daily Traffic Summary

On Fridays, the road seems to be the busiest, mostly because of the additional recreational trips attracted by the amusement and movies centers at the commercial area in Christiansburg. On Sundays, the rest day for almost all businesses, traffic volume is the lowest as expected.

Based on the above and for the coming analysis purposes, we are going to assume the following:

1- The average daily traffic ADT on Route 114 is 11600 vpd (year 2000).

2- For violation rate analysis, the traffic volume observed during the violation survey period at a certain day of the week will be considered as a representative average flow for the other same days as well.

3- For cost-effectiveness analysis, future traffic estimation will be based on year 2000 count and a moderate rate of growth of 3%.

4.2.2 Traffic classification

The traffic fleet served by Route 114 was grouped into three main vehicle classes:

1- Light Vehicles (LV): includes passenger cars of all sizes (small, medium and large).

2- Medium Vehicles (MV): includes light trucks, pick-ups, SUVs and vans.

3- Heavy Vehicles (HV): includes medium and heavy trucks, trailers, and buses.

Tables A4-2a and A4-2b in the Appendix show the traffic classification by hour for week1 and week 2. Almost 98% of the traffic counted were identified and classified by the machines. The other 2 % were put under unclassified (or unknown) category denoted by (UN) in the tables.

Tables 4-2 and 4-3 below summarize the percent distribution of the three classes per day and per direction for the two-week survey based on the total number of classified vehicles. The tables reveal that at least 4 out of five vehicles are light vehicles, Then Medium vehicles ranges from 11% to 17 % whereas heavy vehicles constitute between 1 to 4% of the total traffic.

The comparison of the directional daily classification data between week 1 and week 2 are exhibited in Figures 4-5 and 4- 6. They show that the percent ratios of the three classes have same trend over the two weeks. However, the weekly trend shows that the share of the light vehicles on week ends increases at the expense of the other two classes, since the heavy vehicle class, at those days, is expected to have less truck and bus trips because of less economic activities and schools closure. Moreover, The graphs reveal also that there is almost no or very little variation of the share of each class at the same day of the two weeks indicating a stable pattern of traffic along the road.

Table 4-2: Vehicle Classification by Day & by Direction for Week 1

WEEK 1	Thursday		Friday	Saturday		Sunday		Monday		Tuesday		Wednesday	
Vehicle Class	09/14 E	09/14 W	09/15 E	09/16 E	09/16 W	09/17 E	09/17 W	09/18 E	09/18 W	09/19 E	09/19 W	09/20 E	09/20 W
LV	4809	4587	5757	4919	5017	3995	3877	4686	4369	4882	4613	4698	4482
MV	841	985	897	590	881	574	721	779	962	790	954	739	911
HV	177	191	198	88	84	56	53	193	214	172	216	168	188
UN	136	86	166	152	62	127	71	143	94	144	82	150	103
Total	5963	5849	7018	5749	6044	4752	4722	5801	5639	5988	5865	5755	5684
Total Classified	5827	5763	6852	5597	5982	4625	4651	5658	5545	5844	5783	5605	5581
%													
LV	83%	80%	84%	88%	84%	86%	83%	83%	79%	84%	80%	84%	80%
MV	14%	17%	13%	11%	15%	12%	16%	14%	17%	14%	16%	13%	16%
HV	3%	3%	3%	2%	1%	1%	1%	3%	4%	3%	4%	3%	3%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 4-3: Vehicle Classification by Day & by Direction for Week 2

WEEK 2	Thursday	Friday		Saturday		Sunday		Monday	Tuesday		Wednesday	
Vehicle Class	09/21 E	09/22 E	09/22 W	09/23 E	09/23 W	09/24 E	09/24 W	09/25 W	09/26 E	09/26 W	09/27 E	09/27 W
LV	4859	5574	5239	5376	5339	3747	3764	4261	4629	4401	4700	4354
MV	849	870	1020	764	1022	485	646	899	783	978	804	938
HV	227	191	194	76	81	52	51	175	166	179	206	225
UN	162	133	82	114	48	107	41	58	135	49	174	111
Total	6097	6768	6535	6330	6490	4391	4502	5393	5713	5607	5884	5628
Total Classified	5935	6635	6453	6216	6442	4284	4461	5335	5578	5558	5710	5517
%												
LV	82%	84%	81%	86%	83%	87%	84%	80%	83%	79%	82%	79%
MV	14%	13%	16%	12%	16%	11%	14%	17%	14%	18%	14%	17%
HV	4%	3%	3%	1%	1%	1%	1%	3%	3%	3%	4%	4%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

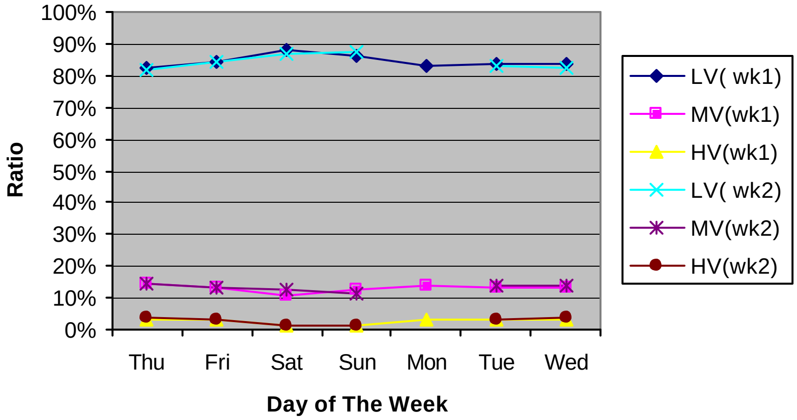


Figure 4-5: Two-week daily Classification in Eastbound Direction

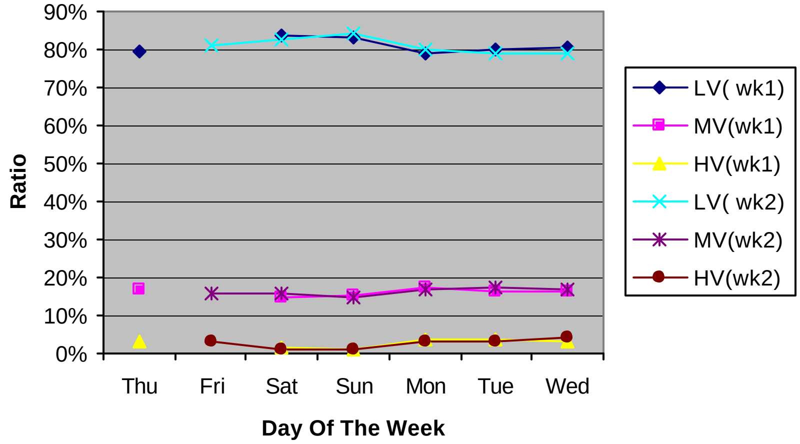


Figure 4-6: Two-week daily Classification in Westbound Direction

Based on the above, there is very little variation among the various classes' shares. For our further analysis, an average based on the two weekly averages (as shown in Table 4-4) is going to be assigned to each class as follows: Light vehicle: 83 %, Medium vehicles: 14%, and Heavy vehicles: 3 %.

Table 4-4: Two- Week Average Share of Vehicle Classes

	WEEK 1		WEEK 2		Average	
Vehicle Class	Volume	%	Volume	%	Volume	%
LV	60691	82.8%	56243	82.6%	58467	82.7%
MV	10624	14.5%	10058	14.8%	10341	14.6%
HV	1998	2.7%	1823	2.7%	1910.5	2.7%
Total Classified	73313	100.0%	68124	100.0%	70718.5	100%

4.2.3 Speed survey

Speed was collected on the designated road section for the three identified vehicle classes: Light, Medium, and Heavy vehicles so that we can get speed distribution for every vehicle type. The speed data has a very important role (as an input) in analyzing the passing maneuvers. Because, once a taking over maneuver starts, the initial speeds for the different vehicles on the scene could crucially shape the final outcome of the maneuver whether it is a safe or a disastrous one.

Traffic speed on Route 114 has been surveyed for two weeks on 15-minute basis. Tables A4-3a&b in the Appendix, summarizes the data on daily basis by class, day and direction for both weeks.

Actually, one might expect significant variation in observed speed between the different vehicle classes. Now let's have a closer look by regrouping the tables in the appendix on class basis as shown in the 12 tables A4-4 (a-d) for the light vehicles (LV), A4-5 (a-d) for medium vehicles (MV), andA4-6 (a-d) for heavy vehicles (HV). Speeds observed along the day per direction for every class were tabulated in 11 speed bins or (levels), starting from speed less than or equal to 25 miles /hour, to less than or equal to 75 miles/hour, with 5 miles/hour increment. In addition, every table is associated with another table showing the cumulative percentages of vehicles running slower or equal to a certain speed bin.

All these 24 tables show actually the distribution of the speed at an acceptable degree of accuracy, and enable us to examine the shape of such distribution. For example, let's start with the speed distribution of light vehicles in the east direction of the first day of survey on September 14, 2000 presented in Figure 4-7.

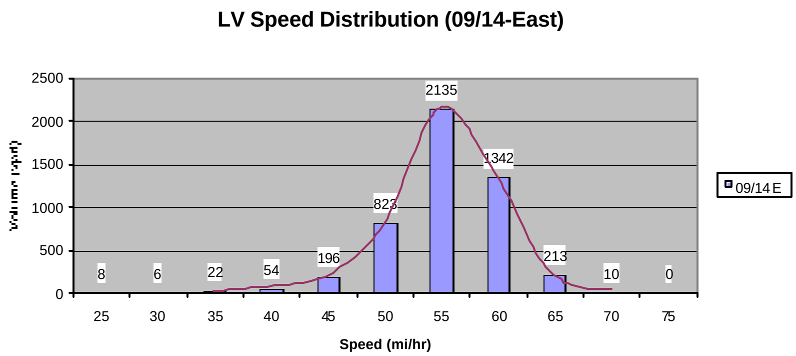


Figure 4-7: Speed Distribution for Thursday 09/14/00 East

What one may conclude from the first look at the chart is that speed is distributed in a bell-like shape, where a prevailing speed falls almost in the middle of the distribution, and the other speed observations fall to both sides of the midpoint speed, in a gradually decreasing number. Typically, This could be considered a normal distribution, a conclusion not far from what transportation planners usually assume, and what other studies for uninterrupted traffic flow show.

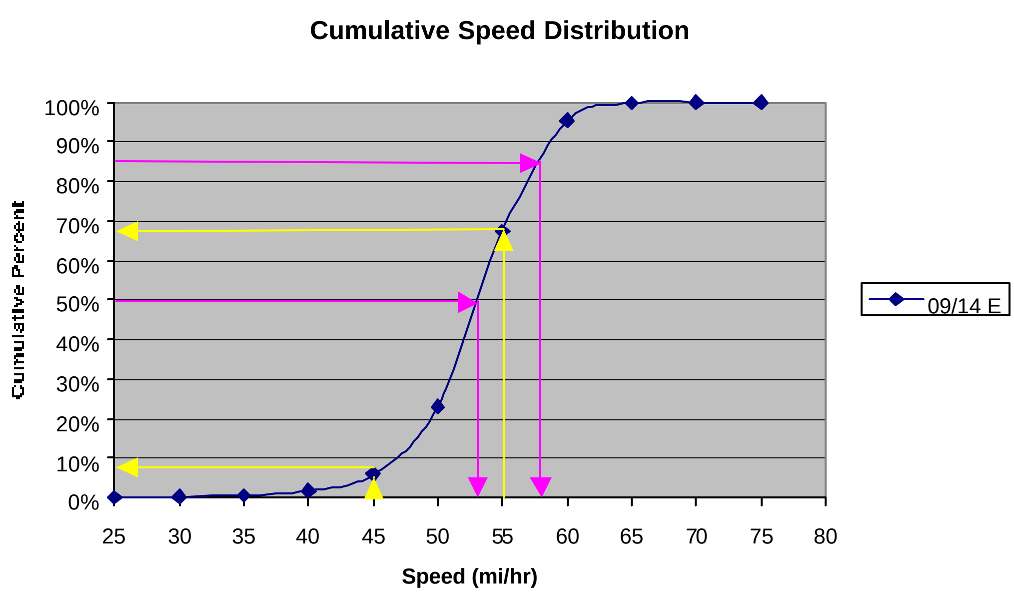


Figure 4-8: Cumulative Speed Distribution for Thursday 09/14/00 East

The cumulative distribution depicted in Figure 4-8 shows that 50 % of the light vehicles reported speed at that day and in the eastbound direction were less or equal 53 mi/hr and that the 85th percentile of observed speed was 58 mi/hr.

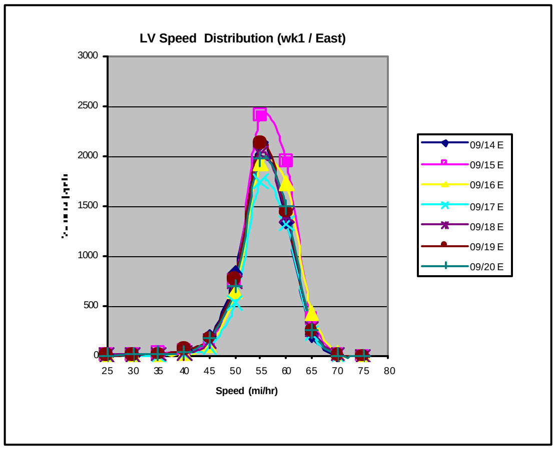
These two figures indicate that there is speeding violation problem on that road knowing that the prevailing speed limit on route 114 is 55 mi/hr (1/3 of the drivers ride at higher speed). Moreover, in order to reduce the risk of crashing, the speed limit on our stretch was reduced to 45 mi/hr few years ago. Yet, only less than 10% of the drivers obey this new regulation.

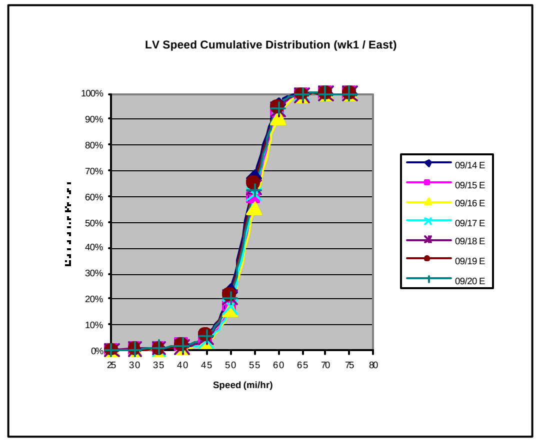
Actually, the remarks drawn above were almost the same for the other traffic direction, other days of the week, and surprisingly for other vehicle class including the heavy vehicles. In fact, every day, by each direction, and by each vehicle class (covered by tables A4-4 to A4-6) was re-represented in two ways: the first shows the speed distribution and the second the cumulative percent for the different levels of speed. Figures 4-9 (a-h) through 4-11 (a-h) exhibit all these 24 tables.

Those figures reveal that almost all the curves show very close distribution shape, and quite similar to what we have discussed above in our case example. The peak of the curves, however, may vary because traffic volume may vary from day to day over the weekdays. As we have shown before the highest peak is on Fridays, and the lowest is on Sundays.

Having said that, we are going to consider the normal distribution as the probability distribution function (PDF) when describing the speed distribution for our simulation. What we still need now is to quantify this distribution for each vehicle class after we examine the patterns of speed distributions for flow directions over the days of the week.

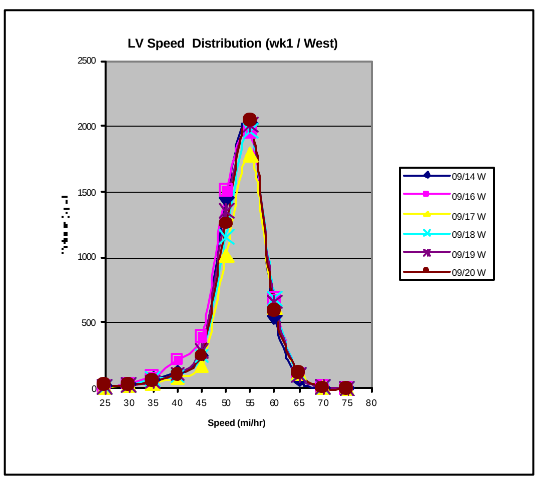
To define a normal distribution we need to determine the mean **(µ)** and the standard deviation **(s)** of the function. An average mean could be approximated from the speed distribution curve and verified at the cumulative 50% ratio, whereas the standard deviation could be estimated from the cumulative distribution curve where the area or (probability) under curve at **(µ + s)** = 84% and **(µ - s)** = 16%

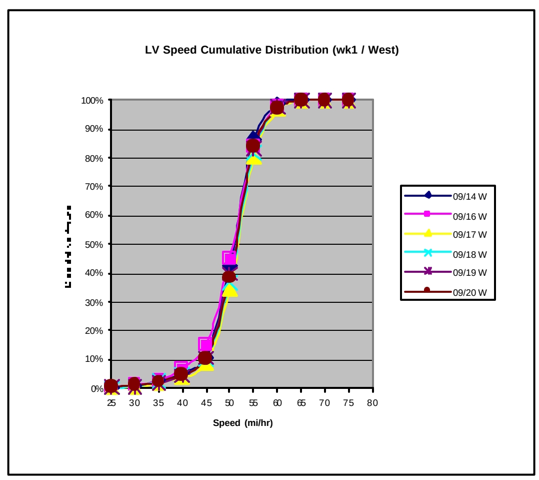




(a) **(b)**

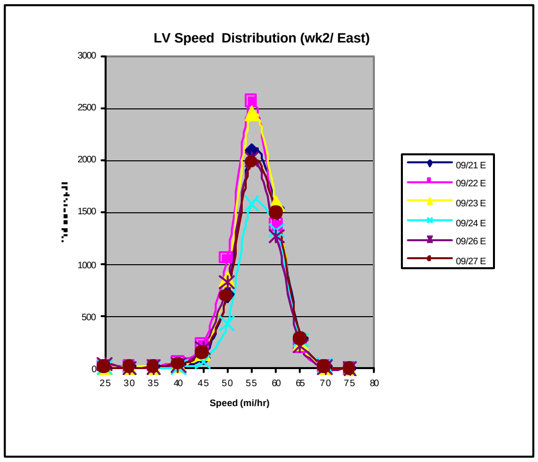
Figure 4-9a,b: Light vehicles Speed Distribution for Week1 - East

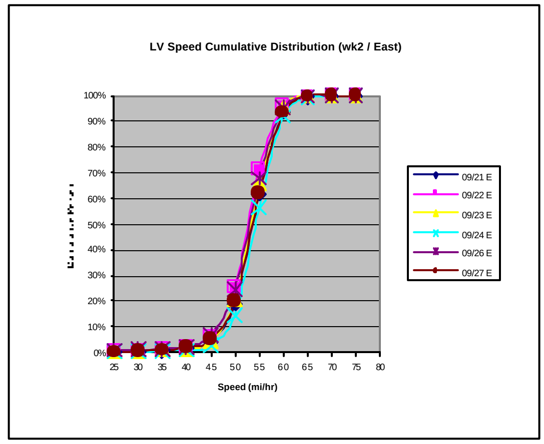




(c) **(d)**

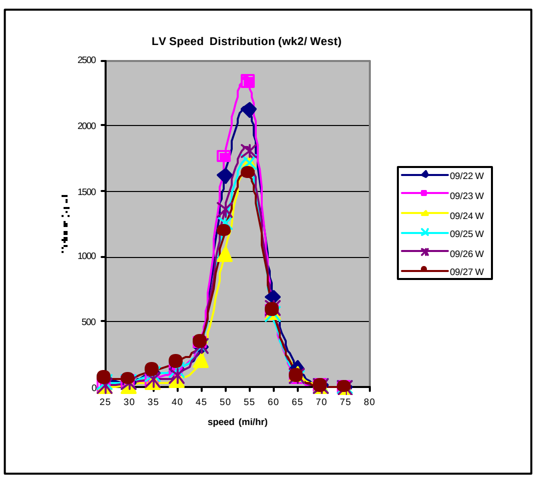
Figure 4-9c,d: Light Vehicles Speed Distribution for Week1 - West

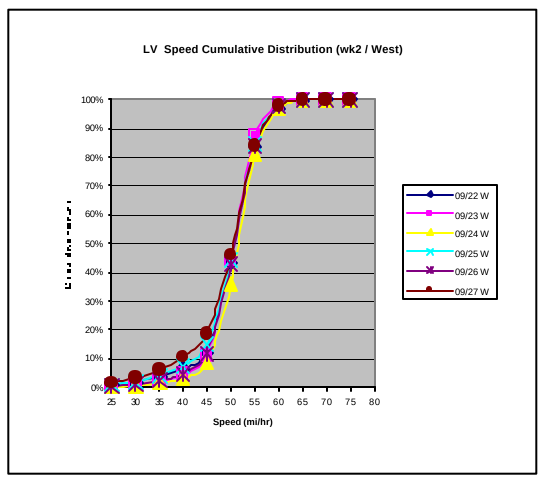




(e) (f)

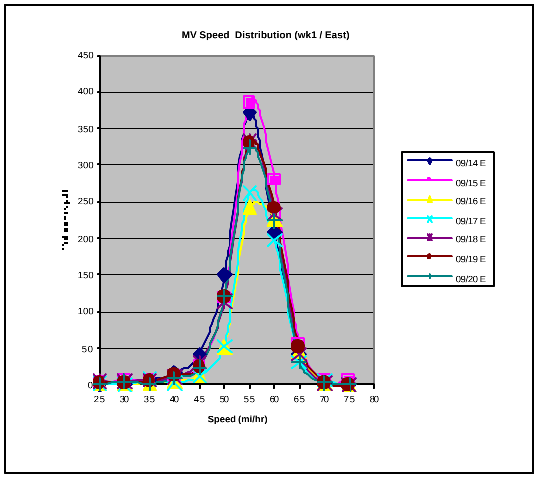
Figure 4-9e,f: Light vehicles Speed Distribution for Week2 - East

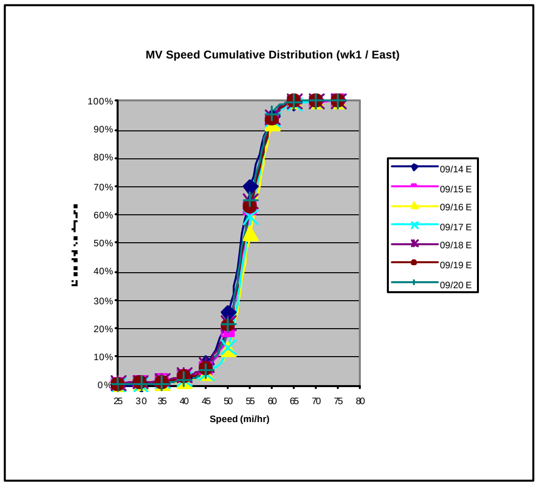




(g) (h)

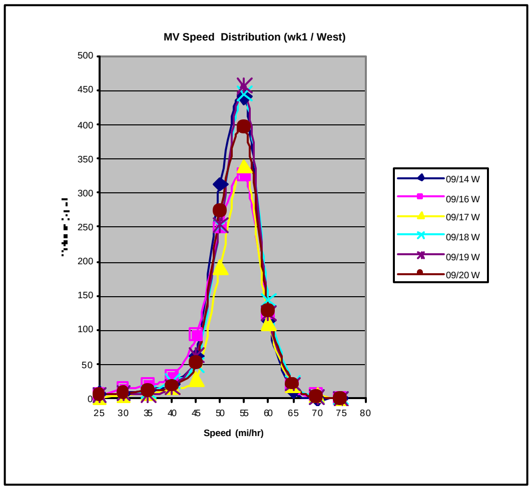
Figure 4-9g,h: Light Vehicles Speed Distribution for Week2 - West

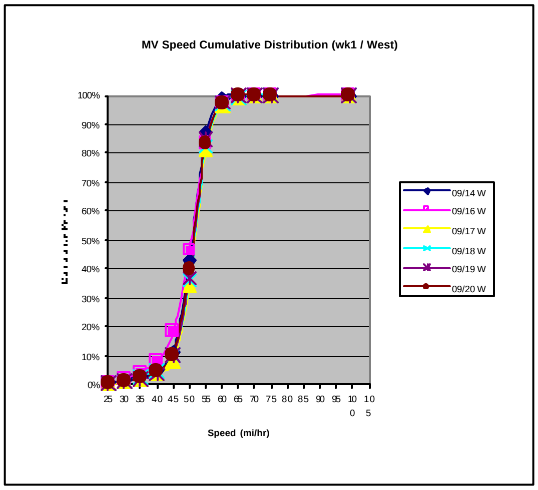




(a) **(b)**

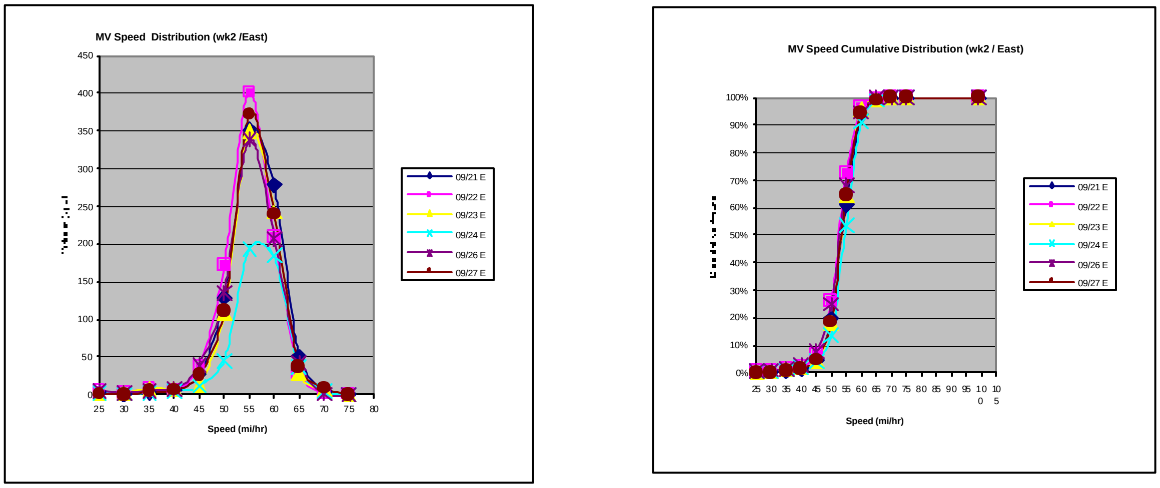
Figure 4-10a,b: Medium vehicles Speed Distribution for Week1 - East





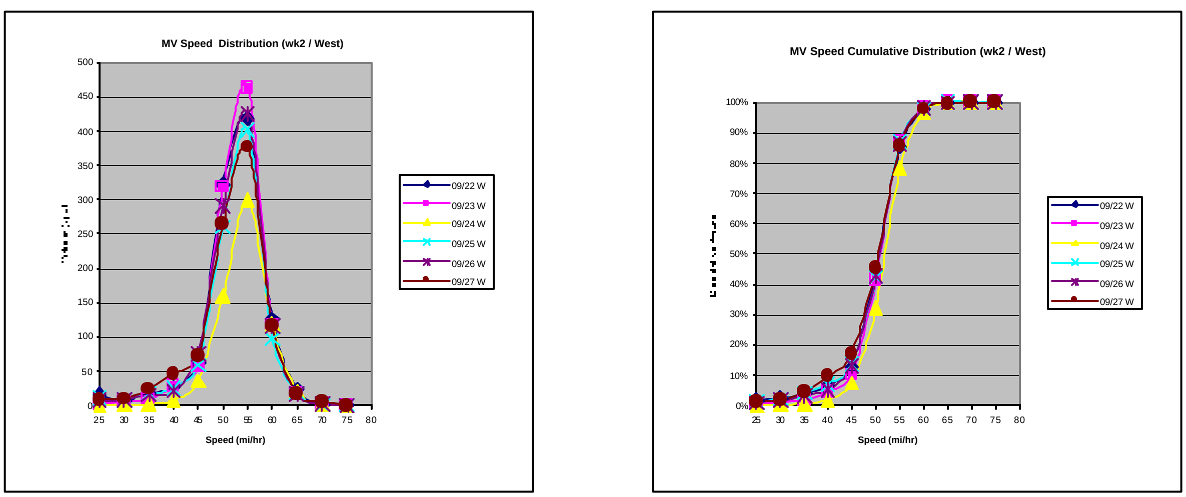
(c) **(d)**

Figure 4-10c,d: Medium Vehicles Speed Distribution for Week1 - West



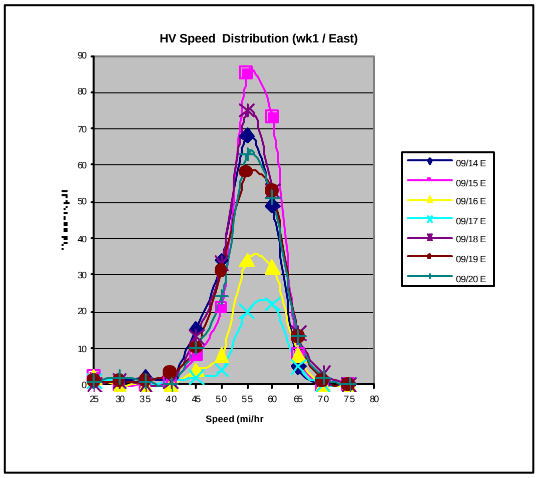
(e) **(f)**

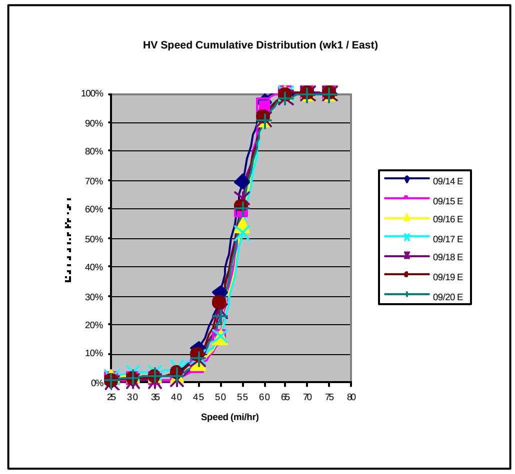
Figure 4-10e,f: Medium vehicles Speed Distribution for Week2 - East



(g) **(h)**

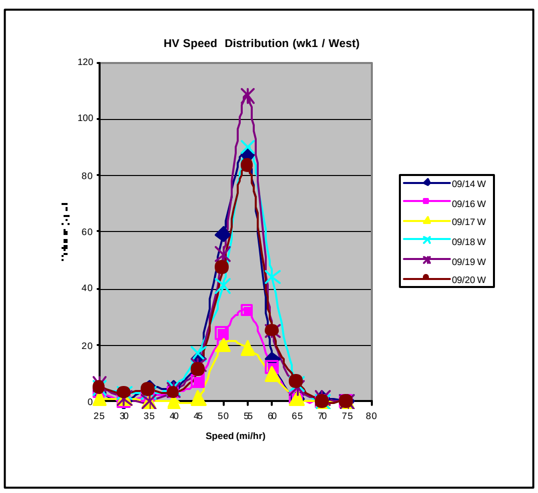
Figure 4-10g,h: Medium Vehicles Speed Distribution for Week2 - West

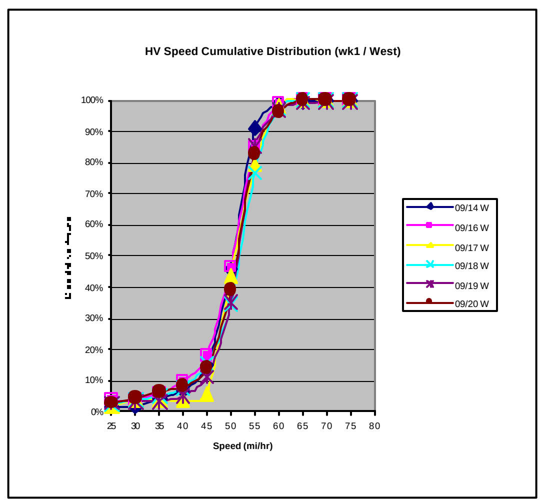




(a) **(b)**

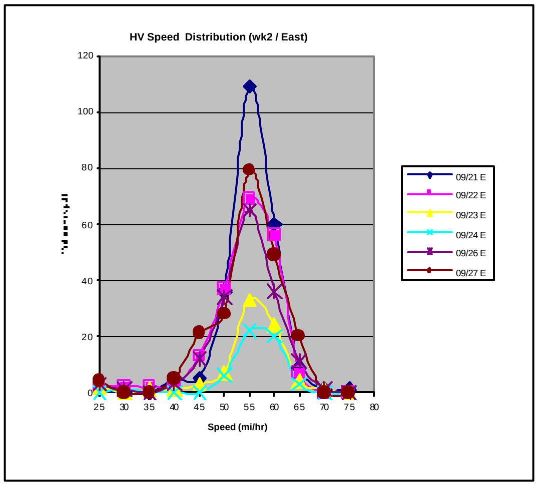
Figure 4-11a,b: Heavy vehicles Speed Distribution for Week1 - East

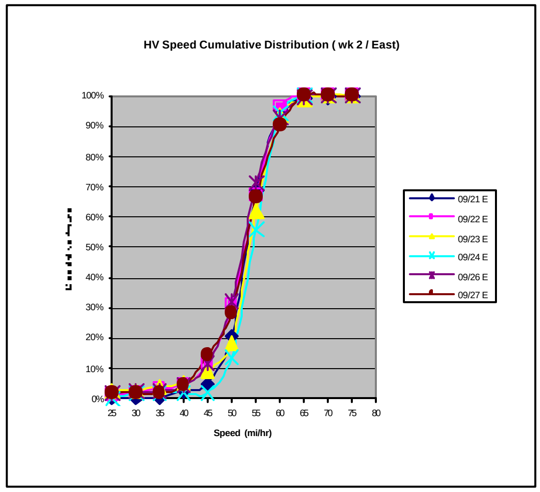




(c) **(d)**

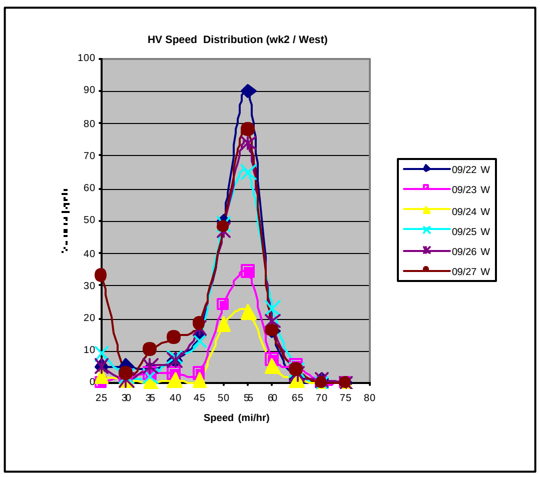
Figure 4-11c,d: Heavy Vehicles Speed Distribution for Week1 - West

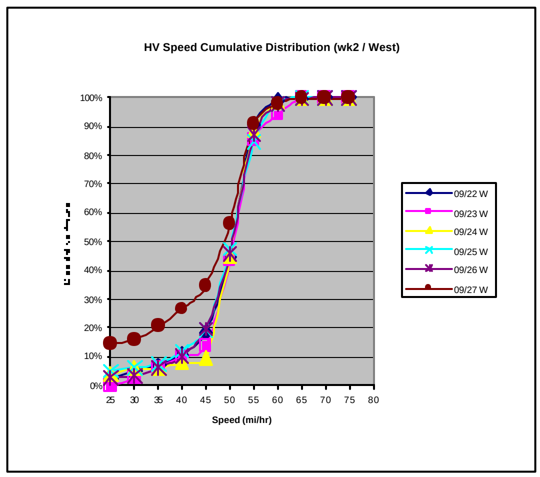




(e) **(f)**

Figure 4-11e,f: Heavy vehicles Speed Distribution for Week2 - East





(g) **(h)**

Figure 4-11g,h: Heavy Vehicles Speed Distribution for Week2 - West

Table 4-5 exhibits the outcome of our approach in approximating the observed speed distribution to a normal distribution function.

Table 4-5: Mean and Standard Deviation Estimation (mi/hr)

	Light Vehicles				Medium Vehicles				Heavy Vehicles			
	Week 1		Week 2		Week 1		Week 2		Week 1		Week 2	
	East	West	East	West	East	West	East	West	East	West	East	West
μ+ s (at 84%)	58	55	58	56	58	55	58	55	58	55	57	54
μ - s (at 16%)	49	46	48	46	48	46	48	46	48	45	47	42
Av. s	4.5	4.5	5.0	5.0	5.0	4.5	5.0	4.5	5.0	5.0	5.0	6.0
Calculated μ	54	51	53	51	53	51	53	51	53	50	52	48
μ (at 50%)	54	52	53	52	54	51	55	51	53	51	53	50

The table shows that there is no much difference between the mean speeds of the three classes. Light vehicles (cars) and medium vehicles (SUVs and light trucks) have almost the same mean speed whereas heavy vehicles (standard trucks) mean is slightly lower. Also, we may notice that the westbound traffic (towards Radford) is a little bit slower than the eastbound traffic (towards Christiansburg). The standard deviation also does not vary much. For the whole directions and classes, s ranges from 4.5 to 6 mi/hr, thus the ratio s/μ revolves around 1/11.

As a conclusion we are going to assume that speed distribution for all traffic follows a normal distribution function. The mean and standard deviation adopted for the different classes and directions are summarized in table 4-6 below.

Table 4-6: Mean and Standard Deviation for the Speed Normal PDF

Vehicle Class	Light Vehicles (LV)		Medium Vehicles (MV)		Heavy Vehicles (HV)	
Direction	East	West	East	West	East	West
μ	54	52	54	51	53	50
s	5	5	5	5	5	5

4.3 Accident Data Analysis

Analyzing accidents that occurred on Route 114 is another essential step to achieve the following two main objectives

1- To better understand the types and characteristics of accidents occurring on Route 114 with a special focus on the head-on crashes.

2- To compare and justify the selection of our site among others to receive the corrective measures that our experimental project suggests.

Our analysis is based on the data provided by VDOT HTRIS accident database which cover all accidents that occurred on that road for the last seven years, namely between January 1994 and November 2000. The data are documented in Appendix A4-7. Every accident is associated with its document number, time and location, direction, environmental conditions, the number of vehicle involved, and the human damages; injuries and losses in lives.

Table 4-7 gives a clear idea about the total number of accident that took place at that facility for the seven years (1994-2000). These accidents were classified based on two attributes: The type of collision and the location where it occurred. For the second dimension, and for comparison purposes, we have considered three kinds of locations:

1- The entire road (5.98 miles), which connects Radford to Christiansburg at Route 460 junction in Christiansburg.
2- The hilly or rolling subset of the road (2.93 miles) between Onyx Drive and Nolen Drive. This part of the road link is characterized by the consecutive vertical crests including the stretch under analysis, and
3- The project site subset, which covers mainly the hill described above in the geometric layout paragraph. This stretch starts from the proximity of Rolling Hills Drive in the east and extends over 0.53 mile to the west towards East Vicker Drive.

Table 4-7: Accidents By Class and Location (1994-2000)

Accident Type	Entire Stretch (5.98 mile)	Percent of total	Hilly Region (2.93 mile)	Percent of total	Project site (0.53 mile)	Percent of total
Head on Collisions	11	6.2%	8	10.5%	5	27.8%
Collisions at Angle	27	15.2%	13	17.1%	1	5.6%
Side Swipe (Same Direction)	3	1.7%	0	0.0%	0	0.0%
Side Swipe (Opposite Direction)	2	1.1%	0	0.0%	0	0.0%
Rear end Collisions	99	55.6%	43	56.6%	7	38.9%
Fixed Object Off-Road	20	11.2%	5	6.6%	2	11.1%
Deer	11	6.2%	5	6.6%	2	11.1%
Non Collision	3	1.7%	1	1.3%	1	5.6%
Fixed Object in Road	1	0.6%	1	1.3%	0	0.0%
Pedestrian	1	0.6%	0	0.0%	0	0.0%
Total Accidents	178	100.0%	76	100.0%	18	100.0%

The table shows that 11 head on collisions took place on the entire road constituting 6.2% of the total 178 collisions. This share, however, increases significantly up to 10.5 % in the hilly region of the road (8 head-on out of 76 collisions), and to 27.8 % in the project stretch (5 head-on out of 18 collisions). The last two percentages are 3 and 9 folds the observed national percentage (3%).

According to the data provided by VDOT HTRIS- Accident subsystem, the daily vehicle-mile of travel VMT on this route is 62974 vehicle-miles (equivalent to an average 10530 vpd). This input was introduced in Table 4-8 in order to calculate the accident ratio per 100-million vehicle-mile of travel on Route 114. It was found that the ratio is about 111 accidents per 100

MVMT for the entire road, which drop to 96 for the hilly region to increase again up to 126 accidents per 100 MVMT in the project road stretch.

Table 4-8: Accidents per 100 MVMT

	Entire Road	Hilly Region	Project Site
Length (mi)	5.98	2.93	0.53
Average Daily Traffic	10530	10530	10530
7- year VMT	160,886,817	78,829,160	14,259,200
7-year Crashes	178	76	18
Crash per 100MVMT	111	96	126

Now, let us examine another aspect of the accident characteristics, which is the severity of the accidents reflected by the amount of bodily, and property damages as shown in Table 4-9.

Table 4-9: Accident Damages by Collision Type and Location

Stretch	Entire Stretch			Hilly Region			Project Site		
Accident Type	Fatalities	injuries	vehicles	Fatalities	injuries	vehicles	Fatalities	injuries	vehicles
Head on Collision	12	29	25	9	20	17	7	15	10
Collision at Angle	0	35	58	0	14	28	0	0	2
Side Swipe (Same Direction)	0	0	6	0	0	0	0	0	0
Side Swipe (Opposite Direction)	0	1	5	0	0	0	0	0	0
Rear End collision	0	105	229	0	65	95	0	13	15
Fixed Object Off Road	0	12	24	0	3	7	0	1	2
Deer	0	5	12	0	5	6	0	1	2
Non Collision	0	5	3	0	2	1	0	2	1
Fixed Object in Raod	0	0	1	0	0	1	0	0	0
Pedestrian	0	1	1	0	0	0	0	0	0
Total	12	193	364	9	109	155	7	32	32
percent of Total	100%	100%	100%	75%	56%	43%	58%	17%	9%
per 100MVMT	7.5	120.0	226.2	11.4	138.3	196.6	49.1	224.4	224.4

As we can see from Table 4-9, head on collisions caused all the twelve fatalities from all accidents that occurred on route 114 during the last seven years. Moreover, the vast majority of the fatal accidents (9 fatalities or 75% of the total) took place in the hilly region between Onyx drive and Nolen drive. Of these accidents, the highest portion occurred on the project site stretch where 7 fatalities constitute around 58 % of the total fatalities that took place on all route 114, but in a distance less than 1/10th of the total road length. The locations of these fatal head-on collisions are depicted on the road section as shown in Figure 4-12 below.

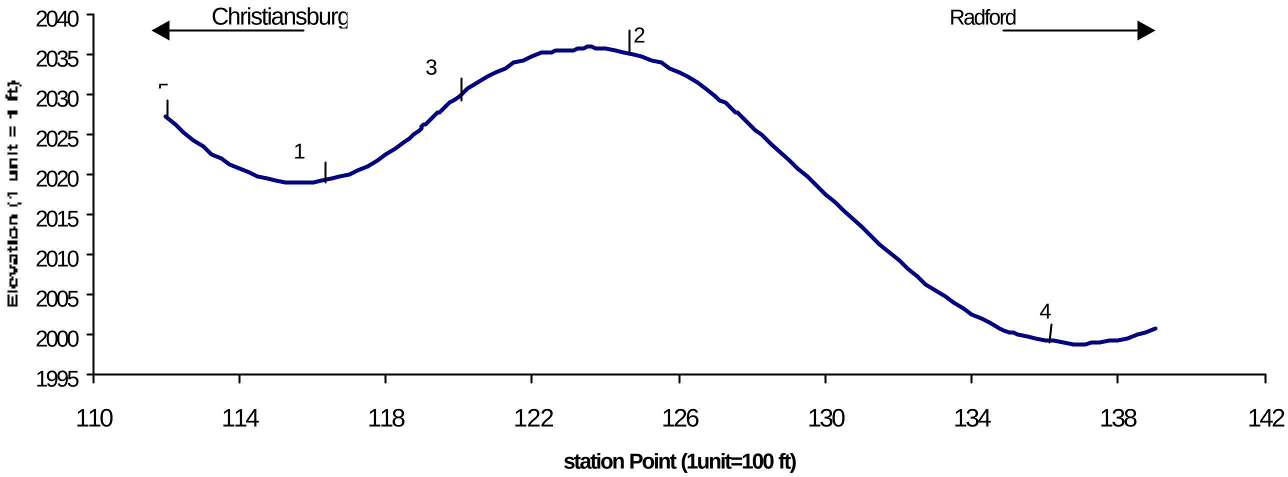


Figure 4-12: Fatal Accidents Locations

4.3.1 Head on Collision Attributes Analysis

A closer and more investigative look at the head on collisions is carried out to better understand their characteristics. This investigation will study the collisions attributes, and will provide comparative analysis between two levels: the whole route and the project site. Tables 4-10 and 4-11 show the following attributes as reported by the police:

Collision Location: As we have explained before, five out of eleven collisions that took place on route 114 occurred on the stretch under study. That means 45% of this type of crashes occurred on 9 % of the road length.

Severity: All head-on collisions have caused severe human losses in terms of bodily damages: injuries, or fatalities, or both. We should recall here that all fatalities reported on this road resulted from head-on crashes only.

Table 4- 10: Head On Collisions On Route 114 (1994 – 2000)

S.No	Doc No.	Date	Node	Weather	Light	Fatality	Injury	No. of Vehicles	Property Damage	Time	Driving Under Influence	Vehicle 1 Type	Vehicle 2 Type
1	1941519	7/5/00	Centerville circle (R)	NR	Daylight	0	2	3	9100	NR	NR	NR	NR
2	1442161	5/13/00	Rolling Hills Dr.	Cloudy	Darkness	1*	9*	2	11000	22	0	Car	Pickup truck
3	1030464	3/29/00	Nolen Dr.	NR	Daylight	1	1	2	12500	NR	NR	NR	NR
4	991251424	4/3/99	West/Vicker Switch Rd.	NR	Darkness	0	3	3	18000	NR	NR	NR	NR
5	973181392	10/31/97	East/Vicker Switch Rd	Cloudy	Darkness	3	1	2	25800	21	1	Car	Car
6	973022263	10/24/97	East/Vicker	Rain	Darkness	1	1	2	16500	20	NR	Car	Car
7	970360502	1/23/97	60-00760(R)	Cloudy	Darkness	1	1	2	10500	22	1	Pickup truck	Car
8	953051545	10/21/95	Centerville Circle	NR	Darkness	3	4	3	3250	NR	NR	NR	NR
9	943412168	12/4/94	East/Vicker	Rain	Daylight	1	1	2	71000	NR	0	Straight Truck	Car
10	943481821	11/26/94	Rolling Hills Dr.	Cloudy	Daylight	1	3	2	21000	15	0	Pickup truck	Car
11	941680608	06/10/94	Centerville circle (R)	Mist	NR	0	3	2	NR	NR	NR	NR	NR
						12	29	25	189550				

NR denotes "not reported"

Table 4-11: Head On Collisions in Project Site (1994 – 2000)

S.No	Doc No.	Date	Node	Weather	Light	Fatality	Injury	No. of Vehicles	Property Damage	Time	Driving Under	Vehicle 1 Type	Vehicle 2 Type
1	1442161	5/13/00	Rolling Hills Dr.	Cloudy	Darkness	1*	9*	2	11000	22	0	Car	Pickup truck
2	973181392	10/31/97	East/Vicker Switch Rd	Cloudy	Darkness	3	1	2	25800	21	1	Car	Car
3	973022263	10/24/97	East/Vicker	Rain	Darkness	1	1	2	16500	20	NR	Car	Car
4	943412168	12/4/94	East/Vicker	Rain	Daylight	1	1	2	71000	NR	0	Straight Truck	Car
5	943481821	11/26/94	Rolling Hills Dr.	Cloudy	Daylight	1	3	2	21000	15	0	Pickup truck	Car
						7	15	10	145300				

NR denotes "not reported"

***** Originally, the accident resulted in 10 injuries. One of the injured victims passed away after few days.

At the entire road level, a head-on accident would result in on an average 1.1 fatalities, 2.6 injuries, and 2.3 involved vehicles. The average property damage, which mainly include the cost of vehicles wrecked, is about $ 7600 per vehicle involved.

At project site level, those averages turned to be 1.4 fatalities, 3 injuries and 2 involved vehicles. The property damage is about $14500 per vehicle involved.

Based on the above, the figures show explicitly that head-on collisions at the selected area of study are more frequent and losses are even more severe than the rest of the road. This would emphasize the importance of finding a way to avoid such heavy losses, and the correctness of selecting the hill we are focusing on in our new experimental approach.

4.3.1.1 Time of Occurrence

Six out of ten reported accidents at the entire road, and three out of the five accidents that occurred on the project site, that is 60 % of the accidents, were reported to occur during nighttime, whereas the other 40 % have occurred during daytime. The implication of such remark is that violations might be more frequent during times of day where the traffic is light. Under these conditions violators could be expecting to have full safe passing. They might be also encouraged by the fact that it is less likely to be caught for their illegal action in the darkness.

4.3.1.2 Environmental Condition

Weather could sometimes affect the quality of driver's visibility for long distances. The accidents detailed report seem to specify the weather condition only when it is believed by the reporter that the prevailing weather at the moment of accident could have negative effect on the clear visibility of the drivers or their capability to control their vehicles, such as, rain, snow, fog, mist, etc. Here it is worth noting that different weather conditions have different degree of impact on driver's environmental conditions. For instance we may expect more difficult driving condition during rainstorm more than during rain shower weather, which in turn is more difficult than during cloudy weather. In addition, every weather condition per se could have many levels of intensity that might affect driver behavior and reaction differently.

As Tables 4-10 and 4-11 indicate, out of the 11 head-on crashes, 2 were reported for rainy weather, 1 misty and 3 cloudy. For the five accidents that occurred in the project site, 2 were reported as rainy and 3 as cloudy.

Anyway, because of the lack of relevant studies, and because of the complex nature of assessing the impact of different weather conditions, such as the rain or the cloud, on drivers' behavior at the moment of the accidents, we are going to ignore this factor when simulating the violation maneuvers assuming it has no effect on the overall outcome.

4.3.1.3 Driver condition

Driving Under Influence DUI has a significant impact on weakening driver mental capabilities, so that the process of conceiving, analyzing, making decisions and reacting will be delayed by precious decisive seconds.

Some of the detailed accident reports do not specify explicitly the condition of the drivers involved in the crash. Others however do. If we want to compare the reported drivers' conditions only, we may say that 2 out of the 5 (40%) cases at the entire road level, and one case out of the four (25%) at the project site level have reported for driving under influence. However, Some suggest that when drivers' conditions is not mentioned in the accident detailed report, that would implicitly mean that there was no DUI observed, otherwise it would have been reported. Consequently, DUI is assumed not to be a contributing factor in the crash. If this is the case, The above ratios would drop down to 2 DUI cases out of 11 (18%) at the entire road level and 1 case out of 5 (20 %) at the project site level, resulting in percentages which look like more close to each other and more consistent.

Based on the above, we will consider 20 % of the violators as DUI cases, an issue that will be discussed in detail in Chapter 8.

4.3.1.4 Vehicles involved

Mostly, a head-on collision involves two vehicles: the violating vehicle and the one coming in the opposite direction. This has been the case in the project site where only two vehicles were reported in every collision. For the entire road, however, Table 4-8 reveals that in 3 out of 11 accidents (27%) there were three vehicles involved in such kind of collision, indicating that a third vehicle, which might be the vehicle that the violator was trying to takeover, is involved in the crash.

Now, regarding the class of vehicles involved in reported crashes, all vehicles are either cars (light vehicles), or pickup trucks (medium vehicles). Unfortunately, the reports do not specify which vehicle was the violating one. In one accident report, which occurred on the project site, a "straight truck" (heavy vehicle) was one of the two vehicles involved in the crash. The other was a car. One may think of the latter as the violator and the truck as the vehicle coming in the other direction. This conclusion actually is supported, by the violations observed during the violation rate survey conducted on the project site (which will be discussed in the next section).

For our further analysis and simulation, we will assume that only two vehicles will be damaged by any unavoidable head-on crash. This assumption, on one hand, is what actually have been seen on the project site and, on the other hand, is leading to a more conservative estimation of property damages. Also, we will assume that only the light vehicle class and the medium vehicle class commit the violation actions, whereas the incoming vehicle in the opposite direction could be any of the three vehicle classes.

4.4 Violation Survey

The violation survey aims at exploring the characteristics of such violations, and at understanding some related measures such as the vehicle that usually commits the violation, when, at what speed and in what direction? Also, The survey aims at estimating the number of solid yellow line crossings, in order to determine the proportion of illegal passing maneuvers currently occurring. Violation rates will be associated with time period, traffic volume, and vehicle type.

This survey was conducted in September 2000 while the machine counters were installed. This kind of arrangement would enable us to get accurate data to determine the violation rate by direction and vehicle class as well.

It is worth noting here that in spite of the vertical curvature, passing is partially allowed on the project site. In fact, the road centerline is marked by double yellow line all over the east side of the hill only, up to about 1010 ft from Rolling Hills drive. On the west side it is one-sided solid yellow for the upgrade traffic coming from Radford. The traffic coming from the other direction (Christiansburg), it is allowed for vehicles to make legal passing as they reach the top of the hill (at the end of the double yellow) heading downgrade, as illustrated in Figure 4-13.

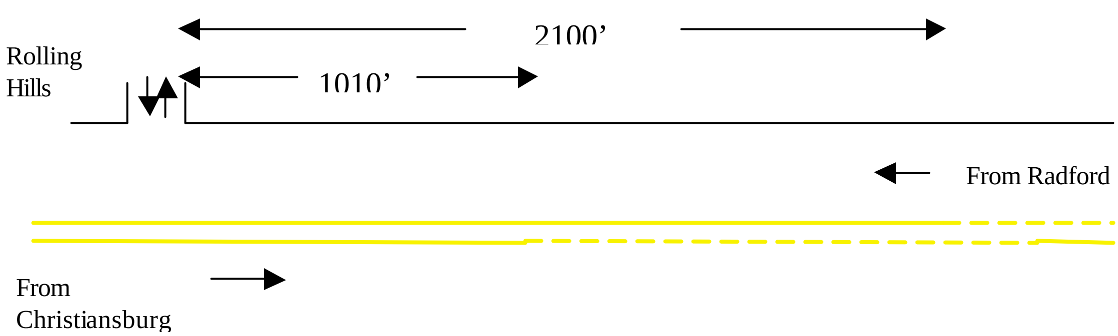


Figure 4-13: Marking Layout at Project Site Centerline

4.4.1 Passings Observed

The survey was conducted over 5 weekdays and one weekend day usually for 6 to 8 hours per day and during daytime only. All kinds of passing maneuvers were counted (legal and illegal), and were reported with their attributes such as: day and time of occurrence, direction of the vehicle passing, the types of passing and being passed vehicles, the maneuver starting point, the estimated speed of both vehicles, some remarks clarifying the circumstances of the passing, and whether the passing was completed or interrupted by another vehicle coming from the opposite direction. Tables A4-8 in the Appendix present the passing maneuvers observed during surveys. We have summarized the results in Table 4-12.

Table 4-12: Summary Of Violation Observations

Day & Date	Survey Duration (Hours)	No. Of Passing Observed	Westbound Violation (To Radford)	Eastbound Violation (To Crs'burg)	Total No. Of Violation	No. Of Violations Completed
Sat.09/16	8.0	7	1	3	4	3
Tues.09/19	6.25	1	0	0	0	0
Wed.09/20	6.0	5	1	1	2	1
Thur.09/21	6.25	2	1	0	1	1
Frid.09/22	6.0	2	0	1	1	1
Mon.09/25	4.25	1	0	0	0	0
Total	**36.75**	**17**	**3**	**5**	**8**	**6**

The table shows that 8 out of the 17 observed passing maneuvers over about 37 hours were illegal. Five out of the eight violations (63%) were committed by the eastbound traffic coming from Radford, and six violators (75%) completed their maneuvers, whereas the two others had to decelerate and return to their right lane as other vehicles appeared in the other direction. Other remarks that the recording observer might have noticed are the following:

1- There is more likely tendency to commit violation in eastbound direction (coming from Radford) than the westbound direction (coming from Christiansburg). This remark could be explained by the longer curve side, which permits the drivers to enjoy relatively a more "distant" visibility, a condition that might encourage potential violators initiating their passing maneuvers.

2- Some of the eastbound violation maneuvers started "legal" at the dashed yellow line (outside the detection zone), but ended "illegal" at the solid yellow line on the upgrade slope of the vertical curve.

3- The westbound traffic has shorter visibility distance. Yet, 3 violations were reported. All westbound violations (3 observations), however, were related to slow (or sudden slowing) of vehicles ahead causing trailing drivers eager (and sometimes angry) to overtake them. Fortunately, two of them succeeded in making the full passing maneuver safely because their locations were close enough to the peak, which enable the drivers to have enough sight distance to the opposite eastbound direction before they started crossing the solid yellow line. The third maneuver however was restrained when a vehicle showed up in the opposite direction.

4- All violating vehicles observed were either light vehicles (cars) or medium vehicles (SUV or light truck). The first consists 75% of the observed violations (6 out of 8 violations), while the latter consists the rest 25 %. The ones who have been passed were any of the three vehicle classes.

5- Finally, at the moment when a vehicle is taking over another vehicle, the difference between the speed of the passing vehicle and the one being passed was (subjectively) estimated from 10 to 25 mile per hour, depending on the case circumstances. This means that the difference of speed at the moment when such maneuvers start could be sometimes less than 10 mile per hour.

Now, we are going to investigate another aspect of the violations: Do they have something to do with traffic volume? Are they affected by congestion?

In order to get a satisfying answer, we are going to examine the traffic flow at the 15-minute period as reported by the machine counters at the moment when the violation took place, determine its level of service (LOS), and conclude what is the prevailing LOS associated with those violations.

Table 4-13 lists the violation cases, day and time of occurrence, their directions, traffic volumes in both directions at that 15-minute period and the calculated LOS using Highway Capacity Manual (HCM) for 2-lane rural road analysis approach. In The capacity analysis the road was assumed No-Passing rural of rolling terrain type, 12-feet lane, 4-feet shoulder and truck share of 3% of the total traffic (as found in the classification survey).

Table 4-13: LOS Of The 15-Minute Violation Period

Day & Date	Time	Violator Direction	15-min Volume in Violation Direction	15-min Volume in Opposite Direction	15-min 2-awy Volume	Equivalent Hour Volume	LOS
Sat. 09/16	8:45 AM	Westbound	41	74	115	460	B
Sat. 09/16	7:35 AM	Eastbound	47	46	93	372	B
Sat. 09/168	12:25 PM	Eastbound	116	106	222	888	C
Sat. 09/16	7:07PM	Eastbound	77	98	175	700	C
Wed. 09/20	10:02 AM	Eastbound	71	41	112	448	B
Wed. 09/20	6:20 PM	Westbound	116	105	221	884	C
Thur. 09/21	5:04 PM	Westbound	135	102	237	948	D
Fri. 09/22	9:23 AM	Eastbound	86	53	139	556	B

The table shows that violations were committed while the traffic was light and enjoying good levels of service. All of the analyzed LOS was either B or C except one case showing (low) D, knowing that the typical capacity of the 2-lane rural is 2400 pcu/ hr in both directions. For the project road stretch, and due to the prevailing geometric and traffic conditions, the adjusted capacity found was ranging from 2100 to 2200 pcu/hr.

Here we should notice that the concluded LOS are only for the daytime violation cases observed during the 6-8 hours survey, which usually covered the peak-hour period. Let us recall here from the head-on accidents history on our road stretch, that 60% of those accidents occurred during nighttime. Therefore, we may draw a conclusion that violations are committed in the nighttime too, and consequently we may expect the LOS at that time is much better than the daytime's since the traffic volume is significantly less.

As a result of the above, one conclusion we could draw is that violations are more likely to occur when the traffic is low. This conclusion is quite reasonable for two reasons:

a- For potential violators, the drivers – especially the risk takers- are more likely encouraged by the low traffic, because they expect less probable vehicle coming from the other direction, so it might not endanger their "courageous" act.

b- The conclusion is consistent with the five accidents that occurred on the project site. The exact times of the reported four accidents were: three accidents occurred in nighttime between 8-10 PM (usually at LOS = B), and one in daytime at 3:00 PM (LOS = C).

4.4.2 Violation Rate

Violation rate is the scale that we are going to use for estimating the number of violation acts that the system will face during its lifetime, and the number of maneuvers that we need to simulate in order to assess the effectiveness and worthiness of the system as well.

Referring to the violation survey, the violations observed have been associated with the traffic volumes per direction that were crossing the area during the survey periods. Table 4-14 summarizes the findings of our analysis.

Table 4-14: Violation Rates Observed (per 10,000 vehicles)

Day& Date	Sat. 09/16		Tues.09/19		Wed. 09/20		Thur. 09/21		Fri. 09/22		Mon. 09/22		Total	
Hours	8.0		6.25		6.0		6.25		6.0		4.25		36.75	
Direction	E	W	E	W	E	W	E	W	E	W	E	W	E	W
No. Of Violations	3	1	0	0	1	1	0	1	1	0	0	0	5	3
Traffic Volume	2809	2380	2468	2218	2316	2040	2534	2192	2774	2235	1689	1516	14590	12581
Violation Rate	10.7	4.2	0.0	0.0	4.3	4.9	0.0	4.6	3.6	0.0	0.0	0.0	3.4	2.4

The table shows that there is a variation in the violation rate among the days of the week: No violation was observed during 10.5 hours of watching in two days, whereas 4 observations have been caught during 8 hours in one weekend day. If we want to take traffic volume as the basis to compare the frequency of violations – which is a more reasonable approach-, we find that the rate ranges from 0 to 10.7 per 10,000 vehicles with an average of 2.9 in both directions. However, we have seen earlier that there is tendency to commit violations in the eastbound traffic coming from Radford more the westbound traffic. Hence, we examined the directional violation rates, and results depicted in the table shows that the eastbound violation rate observed is 3.4 per 10,000 vehicles, 44% more than the westbound rate (2.4 per 10,000).

It is worth noting here that all eastbound violations were committed without having enough sight distance, whereas 2 out of 3 (or 1.6 per 10,000) violations committed in the westbound directions were made while the vehicles were close enough to the peak to have long sight distance before they started their maneuvers.

Let us recall here that small vehicle class committed 75% of those violations, and medium vehicles committed the rest 25%. In addition, knowing that light vehicles share is 83 % of the total fleet, and medium vehicles have 14% share, Therefore, we may specify the violation rates by direction and by vehicle class as estimated by Table 4-15.

Table 4-15: Violation Rates by Direction and Vehicle Class (per 10,000 vehicles)

Direction	**Eastbound**	**Westbound**
Traffic Volume	14590	12581
LV volume	12110	10442
MV volume	1695	1462
LV violations	4	2
MV violations	1	1
LV violation rate	**3.3**	**1.9**
MV violation rate	**5.9**	**6.8**

As a conclusion, and for the coming analysis we are going to assume the following:

1- The number of violations committed will be estimated on traffic volume basis over the project lifecycle.
2- Only light and medium vehicles will be assumed potential violators.
3- The violation rates adopted will be differentiated by direction and by vehicle class. The values of violation rates will be those shown in table 4-14.
4- As for the simulation which will be made for those violations lacking enough sight distance, a 3.4 and 0.8 violations rates per 10,000 vehicles will be adopted for eastbound and westbound respectively resulting in around 900 violations per year to be simulated.
5- These rates will be assumed fixed over the whole analysis period. The implication of such assumption is that the moderate growth of traffic on this road for the project horizon, will not affect deeply the current levels of service, which are dominantly B and C, especially for the non-peak periods. Hence, the rate of violations will not be affected by those slight changes due to the growth of the flow.

Finally, based on the above and for the current level of traffic, we may expect about 3.4 violations per day, 101 per month, or about 1228 per year in both directions, the vast majority of them was committed without having enough passing sight distance. So, one might wonder whether the "human" intelligence is always able to succeed in avoiding the tragic consequences of his own "human' voluntary mistakes? The best answer for that question is no doubt the list of fatal accidents and victims we are still taking record of, so far!