Phase 1 Final Report

SHRP2 Implementation Assistance Program

Concept to Countermeasure – Research to Deployment Using the SHRP2 Safety Data

Do High Visibility Crosswalks (HVCs) Improve Pedestrian Safety?

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Robert Limoges (NYS DOT)

Alan Blatt, Kevin Majka Ph.D., John Pierowicz (CUBRC)

Panagiotis Ch. Anastasopoulos Ph.D., Tawfiq Sarwar, Courtney Bentley (SUNY Buffalo)

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1. Introduction

Traffic crashes in the U. S. over the 5 year period from 2009 to 2013 killed more than 22,400 pedestrians and injured about 326,000 pedestrians [NHTSA 2013, CDC 2015]. Making roads and highways safer for pedestrians is an important national goal. It is also an important goal and focus in New York State [NYS 2015]. In support of this goal, many strategies have been studied to improve pedestrian safety, including: traffic calming countermeasures (i.e., vertical deflections, horizontal shifts and roadway narrowing), passive markings and signage (e.g., high visibility crosswalk markings), and active signage / control devices (e.g., automatic video pedestrian detection, smart lighting, high intensity activated crosswalk).

Our Phase 1 project focused on one of the relatively low cost, widely employed pedestrian safety strategies, the use of High Visibility Crosswalk (HVC) markings. The placement and effectiveness of HVC markings continues to be subject of concern in the traffic safety community. With that in mind, the overall goal of the Phase 1 Project was to demonstrate the feasibility of evaluating the effectiveness of the HVCs to improve pedestrian safety at uncontrolled locations using SHRP2 NDS data and RID data collected at the Erie County, NY SHRP2 test site. To accomplish this we analyzed the driving behavior of SHRP2 participants at 3 uncontrolled locations. At two intersections we were able to acquire traversal data both before and after HVC installation. At the third location only post HVC installation data was available. These data permitted a rigorous evaluation of HVCs, while controlling for a variety of factors, including: intersection and roadway geometric characteristics; traffic characteristics; time and date of the trips; lighting, pavement and weather conditions; driver socio-economic characteristics; and vehicle characteristics.

To accomplish our goal seven Phase 1 project objectives were established. These objectives are summarized in Table 1-1 along with the objective outcome. As noted in the Table, all of the objectives of the Phase 1 Project were achieved.

Table 1-1 Phase 1 Project Objectives and Outcomes

Project Objective	Objective Outcome
1- Identify locations where HVCs were installed during the SHRP2 NDS data collection period.	Successful. Six intersections were identified meeting the criteria.
2- Identify roadway links for locations of interest using the RID database.	Successful.
3- Identify SHRP2 NDS participant transversals of the locations of interest both prior to and after HVC installation.	Successful.
4- Select transversals for analysis and acquire SHRP2 NDS forward video and time series data.	Successful.
5- Analyze the acquired data and create a research database	Successful
6- Demonstrate analysis methodology and produce model results	Successful
7- Produce a Phase 2 Plan using the Phase 1 experience and results.	Successful

2. Literature Review

The literature review performed prior to the start of Phase 1 was updated with recently published relevant papers. Several papers of interest were identified and their findings were used to help formulate the Phase 2 program. Two examples of the pertinent papers are summarized below:

- The primary objective of a recent paper was to evaluate the effects of parallelogram-shaped pavement markings on vehicle speeds and speed violations in vicinity of pedestrian crosswalks on urban roadways in China. The speed data analysis results showed that parallelogram-shaped pavement markings significantly reduce vehicle speeds and speed violations in vicinity of pedestrian crosswalks. The results also showed that the influence area of parallelogram-shaped pavement markings was generally less than 0.3 km. Drivers usually start to decelerate vehicle speeds at about 100 to 150 meters ahead of the pedestrian crosswalks and vehicle speeds are recovered at about 100 to 150 meters after pedestrian crosswalks. [Guo, Liang, Wang, 2015]

- A recent study reports that the driver reaction time to a vehicle-pedestrian conflicts differ depending on whether the pedestrian enters into the road area from the left or right. Driver reaction times were found to be greater when pedestrians enter the road area from the left. The study determined reaction times from an analysis of drivers' use of the accelerator pedal, brake pedal and the steering wheel [Jureck, Stańczyk 2014].

3. Data Used

A key element in our Phase 1 project was the ability to identify appropriate crosswalk locations for analysis in the SHRP 2 NDS New York test site data. Using information provided by NYS DOT Region 5, and other local data sources (Table 3-1), we identified 18 locations in the New York SHRP2 NDS test site with HVC markings. We believe that additional locations of interest exist in within the test site, however, 18 locations were considered to be sufficient for the purposes of the Phase 1 efforts. Six of the 18 locations were determined to have had HVC markings installed during the SHRP2 NDS data collection timeframe and they offered the opportunity to obtain trip/traversal data thru the locations prior to and after the HVC was installed. The remaining 12 locations had HVCs installed prior to the beginning of the SHRP2 NDS data collection period and thus, no trip data prior to the HVC installation was available.

It should be noted that 5 separate data requests were made to VTTI to obtain data. The first request provided information, shown in Table 3-2, on all of the traversals through all of the 18 locations of interest. These data were reviewed and we chose to request NDS trip data for 5 of the 18 intersections.

Table 3-1 Phase 1 Subsidiary Information

Data Element - Intersection	Data Source
Intersection location (latitude/longitude)	NYS DOT / RID
Intersection configuration (four way, "T"	NYS DOT / RID
Speed limit	NYS DOT / RID
HVC presence	NYS DOT / RID
HVC type	NYS DOT / RID
Vehicle traffic count	GBNRTC*
Pedestrian traffic count	GBNRTC*

* GBNRTC – Greater Buffalo Niagara Regional Transportation Council

Table 3-2 Identification of Trip Data Elements

Data Elements	
File ID	Vehicle Heading (at point closest to HVC location)
Participant ID	
Participant Gender	Trip Day of Week
Participant Age Range	Trip Month
Vehicle Make	Trip Year
Vehicle Model	Trip Binned Hour

Four subsequent requests were made for time series and forward video data for specific trips of interest. The data provided in these requests are shown in Table 3-3. The strategy used for the requests was to focus on:

- Trips made by vehicles designated by SHRP2 as "prime" and "subprime". The SHRP2 NDS program categorized vehicles according to the amount of control data that could be collected. 'Prime' and 'sub-prime' vehicles provided the maximum amount of vehicle control data in the time series data,
- Trips in all gender and age categories,
- Trips by participants making many trips through the intersections, as well as trips by participants making only a small number (i.e., less than 5) trips thru the intersections.
- Trips occurring in a period six months before and six months after the installation of the HVC.

After inspection of the received data, three locations were selected for the Phase 1 analyses. Two of the locations were at uncontrolled intersections (i.e., HVC 5 and HVC 6) and provided trips before and after the HVC was installed. One location (i.e., HVC 18) was at an uncontrolled mid-block location and only provided trips after the HVC was installed. It was selected because it had a relatively high pedestrian traffic count.

Table 3-3 Time Series Trip Data Description

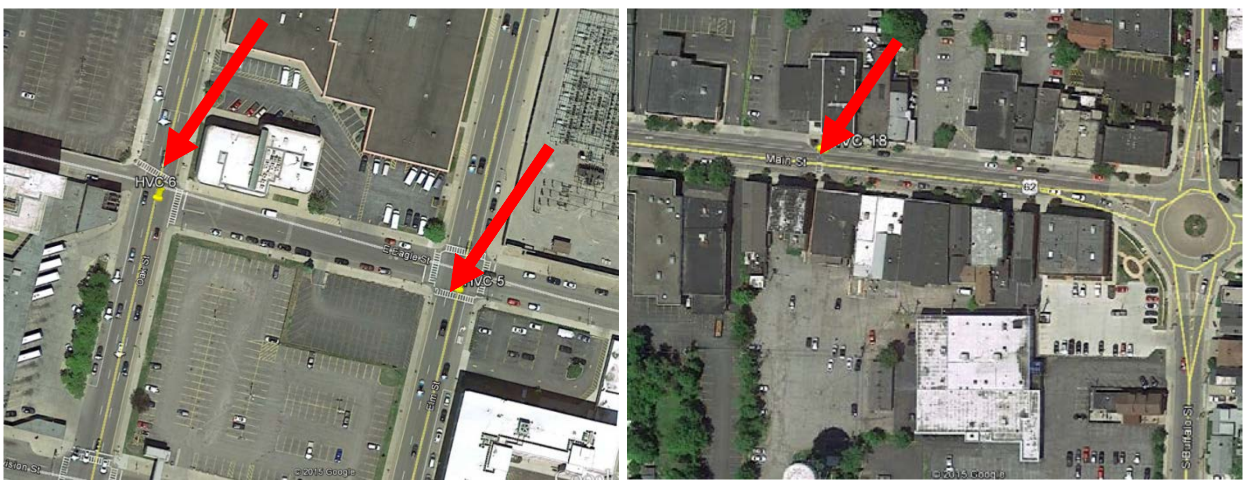
Variable	Description
Date	Exact date is reported as three variables (i.e., month, day, year)
Event ID	Numeric value assigned by VTTI for a sub-set of time-series and video data within a File ID file
File ID	Numeric value assigned by VTTI for the time series and video data for one participant trip. A trip is defined as one vehicle 'ignition-on' to 'ignition-off' cycle
Acceleration x-axis	Vehicle acceleration in the longitudinal direction versus time (g's at 10 Hz)
GPS Heading	Compass heading of vehicle from GPS (degrees at 1 Hz)
GPS Longitude/Latitude	Vehicle position longitude/latitude (degrees at 1 Hz)
GPS Speed	Vehicle speed from GPS (km/hr)
Illuminance Ambient	Ambient exterior light measured in lux at 10 Hz
Radar Target	Numerical value of Target in radar trace data
Radar Range	Range to forward radar targets measured longitudinally from the radar (m at 10 Hz)
Radar Range Rate	Range rate to forward radar targets measured longitudinally from radar (m/s at 10 Hz) (+) for closing, (-) for separating
Pedal, Brake	On or off state of brake pedal
Pedal, Accelerator Position	Percentage of full scale application of the accelerator pedal collected from the vehicle network and normalized using manufacturer specs (0-100% at 10Hz)
Speed, Vehicle Network	Vehicle speed reported by vehicle network (km/hr) at 10 Hz
Steering Wheel Position	Angular position and direction of the steering wheel

Table 3-4 identifies the crosswalks and summarizes the available NDS trip data as well as the data requested and received. The parentheses in the final four columns of the Table 3-4 identify the specific request number associated with the data. It is of interest to note that with the exception of request 5, fewer trips were provided than were requested. This is because our initial requests to VTTI identified specific trips of interest, many of which could not be provided because the crosswalk traversal was too close to the beginning of end of trip and might provide personally identifiable information. Our last request for data to VTTI allowed them to select trips that would not violate the PII criteria.

Figure 3-1 shows aerial views of the three crosswalks. The 'red' arrows indicate the locations of the HVC crosswalks. Although difficult to see, HVC 5 and 6 are located at uncontrolled intersections on one way roads with 3 lanes each. HVC 18 is at a midblock location on a two way road with one-lane in each direction.

Table 3-4 Available SHRP2 NDS Data for Selected Intersections

HVC No.	HVC Name	Roadway Link IDs	Tot. No. of Trips Thru HVC	No. of Drivers Making Trips	Tot. No. of Trips Requested	Tot. No. of Trips Rcvd	No. of Trips Rcvd Prior to HVC Install.	No. of Trips Rcvd After HVC Install.
5	Elm/Eagle (Buffalo)	34107887 34107982	5,284	319	400 (5)	575 (5)	244 (5)	331 (5)
6	Oak/Eagle (Buffalo)	34107857 34107937	4,937	336	446 (2) 41 (4)	347 (2) 15 (4)	142 (2) 8 (4)	205 (2) 7 (4)
18	Hamburg 2	34117407	3,606	158	581 (3)	354 (3)	0 (3)	354 (3)
Totals			13,827	813	1468	1291	394	897



a) HVC 5 and HVC 6 HVC 18

Figure 3-1 Aerial Views of the Three Intersections Used in the Phase 1 Analyses

4. Method of Analysis

There are two important aspects to the analysis methodology. The first relates to the manner in which the forward video data was analyzed. This data was very important to the overall analysis activities and one of the keys to the Phase 1 success was the development of procedures to efficiently inspect and reduce the video data. The process of analyzing the videos involved the determination of an upstream benchmark point for each intersection location and direction. The benchmark points were selected to represent the approximate location where drivers are able to see and react to the HVC. They were also selected based on easily identifiable locations in the videos both before and after the HVC was installed (i.e., landmarks such as buildings and light poles were used). Each video was reviewed and the time that the vehicle crossed the benchmark and HVC locations was recorded. Additional information was also recorded, such as pedestrian presence, vehicle's lane position, preceding and parked vehicles' presence, the level of obstructed visibility of the HVC, windshield condition and wipers' usage, weather conditions, pavement surface conditions, and lighting conditions. Using the time stamps on the video, the time series data were matched with the rest of the trip data. Since the on-board vehicle equipment records information at intervals, the exact values of variables at the benchmark and HVC locations were interpolated.

The selection of the benchmark points for all locations was based on the stopping sight distance (i.e., the reaction distance plus the breaking distance). Since all three locations had a 30 mph speed limit, the required stopping sight distance (assuming a 2.5 sec reaction time) is 47 m. Therefore, the benchmark points on the two Buffalo locations were set about 50 m before the crosswalk. For the Hamburg location, a benchmark of about half of this distance (about 22 m) was selected for two reasons. First the Hamburg HVC was at a mid-block location less than 50 m from the upstream intersection, and second, there were no easily identifiable landmarks in the 50 m range. The difference in benchmark positions was tediously addressed through the use of panel effects (random and fixed effects) in the estimated statistical models, and/or through the use of dummy indicator variables for the Hamburg location. Figure 4-1 illustrates the benchmark and crosswalk points in the HVC 6 (Oak/Eagle, Buffalo) location, presented as a snapshot of the forward facing video data.

Figure 4-1 HVC 6 Oak/Eagle: Forward Facing Video With Benchmark and HVC Points

Since there were no pedestrian- motor vehicle crashes in the SHRP2 NDS database and the data selected for our Phase 1 feasibility analyses contained very few pedestrian- motor vehicle conflicts, our analysis of HVC effectiveness was based on surrogate measures of effectiveness, such as vehicle acceleration and speed, brake pedal state, and throttle pedal actuation (TPA) during crosswalk transversals. These surrogate measures were used to capture critical changes in driving behavior at the selected crosswalk locations before and after the HVC installations. The analysis approach included hypothesis tests and estimation of statistical models, with the latter controlling for: roadway and traffic characteristics; frequency (to capture drivers' habitual effects) and day/month/time/year of the trip; lighting conditions; weather conditions; and vehicle and driver characteristics.

Binary discrete outcome (mixed logit) statistical models were estimated, in an effort to identify the role of HVC presence in the statistically significant reduction in speed, acceleration, and TPA, between the benchmark and crosswalk points. In this manner the factors that increase or decrease the likelihood of a driver adjusting their driving behavior were identified. The application of the random parameters (mixed) binary logit model was undertaken by considering the discrete outcomes described above (i.e., the likelihood of a driver reducing the vehicle's speed, acceleration, or TPA. We followed the method of Washington, and started with: [Washington et al. 2011]

$$T_{in} = \boldsymbol{\beta}_i \mathbf{X}_{in} + \varepsilon_{in}, \qquad (1)$$

where: T_{in} is a function determining whether a driver adjusted the vehicle's speed, acceleration, or TPA by a threshold amount or more on a passage n through the intersection; $\mathbf{X}_{in}$ is a vector of explanatory variables; $\boldsymbol{\beta}_i$ is a vector of estimable parameters for outcome i which may vary across observations, and ε_{in} the error term which is assumed to be generalized extreme value distributed (McFadden, 1981). To arrive at the mixed logit model, random parameters are introduced with $f(\boldsymbol{\beta}_i | \boldsymbol{\varphi})$, where $\boldsymbol{\varphi}$ is a vector of parameters of the density function (mean and variance). The resulting outcome probabilities are:

$$P_n(i | \boldsymbol{\varphi}) = \int \frac{e^{\boldsymbol{\beta}_i \mathbf{X}_{in}}}{\sum_{\forall I} e^{\boldsymbol{\beta}_i \mathbf{X}_{in}}} f(\boldsymbol{\beta}_i | \boldsymbol{\varphi}) d\boldsymbol{\beta}_i \qquad (2)$$

where, $P_n(i | \boldsymbol{\varphi})$ is the outcome probability conditional on $f(\boldsymbol{\beta}_i | \boldsymbol{\varphi})$ [Anastasopoulos and Mannering, 2011]. For model estimation, $\boldsymbol{\beta}_i$ can account for variations of the effect of $\mathbf{X}$ on outcome probabilities, with the density function $f(\boldsymbol{\beta}_i | \boldsymbol{\varphi})$ used to determine $\boldsymbol{\beta}_i$. Mixed logit probabilities are then a weighted average for different values of $\boldsymbol{\beta}_i$ across drivers where some elements of the vector $\boldsymbol{\beta}_i$ may be fixed and some may be randomly distributed. Estimation of the random parameters multinomial logit model shown in Equation 2 is undertaken using simulated maximum likelihood approaches, and 200 Halton draws [Bhat, 2003]. For the functional form of the parameter density functions, consideration was given to normal, lognormal, triangular, uniform and Weibull distributions, with the normal distribution consistently providing the best overall statistical fit. In addition to the binary mixed logit models, two sets of random parameter linear regression models were estimated, to determine the driver's reactions prior to crossing the crosswalk. The first set used as dependent variables the change in speed, acceleration, and TPA between the benchmark and crosswalk points; while the second set, estimated separate models of speed, acceleration and TPA at the benchmark and the crosswalk points. The standard linear regression model is given by:

$$Y_i = \beta_0 + \boldsymbol{\beta}_i \boldsymbol{X}_{in} + \varepsilon_{in} \qquad (3)$$

where: Y_i is the dependent variable; β_0 is a constant term; $\boldsymbol{\beta}_i$ is the coefficient of explanatory variable $\mathbf{X}_{in}$ for observation n; and ε_{in} is the error term [Washington et al, 2011]. Subscripts i and n represent the variable and observation, respectively. As in the binary mixed logit models, random parameters were incorporated into the linear regression models to allow for the effect of the parameters to vary across the observations. This feature of random parameters is important, as they can either capture the variable effect of a specific parameter on the dependent variable, or more importantly the effect of other unobserved factors.

5. Research Results

The Phase 1 feasibility analyses focused on vehicle speed, acceleration and TPA during vehicle traversals of crosswalks before and after HVC installation. These preliminary analyses show HVCs play an important role in decreasing speed and acceleration, in brake application, and to a lesser extent TPA. All these can serve as surrogate measures the effectiveness of HVCs in the absence of observable crash data. From the estimated statistical models, it was found that HVCs:

- Decrease the speed, acceleration and TPA at the benchmark and crosswalk
- Decrease the change in speed and acceleration between the benchmark and crosswalk
- Increase the likelihood that the speed and acceleration reduction is going to be above a statistically significant amount
- Increase the likelihood of application of the brake pedal

It is also important to note that the HVC presence combined with the pedestrian crossing sign was found to decrease both speed and acceleration from the benchmark to the HVC location. In short, HVCs can reduce drivers' speed and acceleration (and possibly TPA), which in turn has the potential to increase pedestrian safety at uncontrolled intersections or mid-block locations.

For the locations with available data before and after the HVC installation (i.e., the two Buffalo locations), one tail hypothesis *t*-tests were conducted, to test whether statistical differences exist in terms of reduction (i.e., before the HVC installation to after the HVC installation) in speed, acceleration, and TPA at the benchmark point, the HVC location, and between the two. Table 5-1 presents the average values and the corresponding *t*-test results for the two Buffalo locations. The results indicate that there was a statistically significant (at 0.95 level of confidence) reduction or change after the HVC installation of most measures of effectiveness (in terms of reducing speeds, accelerations, and possibly TPA). This analysis revealed the need to investigate the observed speeds, accelerations, and TPAs between the benchmark and crosswalk points, and their difference between the two points.

For the same two locations, binary mixed logit models were estimated, in an effort to identify the role of HVC presence in the reduction of speed, acceleration, and TPA. The binary dependent variables were 1 if there was a statistically significant (at 0.95 level of confidence) change in each of the three dependent variables, and 0 otherwise. The values of the statistically significant decrease in speed, acceleration, or TPA were estimated based on hypothesis testing (i.e., the speed, acceleration and TPA decreases that correspond to the 0.95 level of confidence were identified as 1.17 km/h, 0.005 g, and 1.339 or more for the Elm/Eagle location, and 1.30 km/h, 0.010 g, and 3.369 or more for the Oak/Eagle location, respectively, and those were compared to the observed values in order to denote 1's and 0's for the dependent variables). A fourth binary mixed logit model was estimated for the brake pedal: the dependent variable was 1 if the brake was applied anytime from 2 seconds before reaching the benchmark and after crossing the HVC location, and 0 otherwise. The estimation results of these models are presented in Table 5-2.

Table 5-2 shows that the HVC-related variables decreased the speed and acceleration by at least the aforementioned amounts, and they also increased the likelihood of application of the brake pedal. However, the TPA was not statistically significantly affected by the HVC presence, possibly due to the limited amount of available data, which warrants further investigation.

Table 5-1. Average Speed, Acceleration and TPA, Before and After HVC installation, and Corresponding *t*-tests

Variable	Elm/Eagle Location			Oak/Eagle Location			Both locations		
	Before	After	*t*-score	Before	After	*t*-score	Before	After	*t*-score
Avg. speed at benchmark (*km/h*)	53.39	50.04	4.065*	52.25	50.09	2.556*	52.84	50.06	4.723*
Avg. speed at HVC (*km/h*)	54.82	50.96	4.512*	54.42	52.61	1.711*	54.63	51.51	4.770*
Avg. speed difference between benchmark and HVC (*km/h*)	1.43	0.92	1.172	2.17	2.52	0.438	1.79	1.45	0.844
Avg. acceleration at benchmark (in *g*)	0.019	0.013	1.829*	0.016	0.019	0.333	0.018	0.015	0.636
Avg. acceleration at HVC (in *g*)	0.025	-0.003	7.536*	0.009	0.012	0.526	0.017	0.002	4.578*
Avg. acceleration difference between benchmark and HVC (in *g*)	0.006	-0.016	4.471*	-0.007	-0.007	0.041	-0.001	-0.013	2.884*
Avg. TPA at benchmark	12.92	11.55	1.352*	16.32	16.78	0.168	14.54	13.25	1.009
Avg. TPA at HVC	12.53	10.43	2.135*	12.74	14.10	0.652	12.63	11.62	0.978
Avg. TPA difference between benchmark and HVC	-0.39	-1.12	0.631	-3.58	-2.69	0.319	-1.91	-1.63	0.218

Asterisks denote statistically different values at the 0.95 level of confidence (corresponding *t-score* is 1.645).

More specifically, presence of HVC had mixed effects on the acceleration decrease model, with a prominent increase (for 88% of the observations) of the likelihood that the acceleration will decrease by at least 0.005 g for the Elm/Eagle location, and 0.010 g for the Oak/Eagle location, due to the HVC installation. For the brake pedal application model, the HVC coupled with pedestrian sign presence increased the likelihood of brake application. It was also found that the presence of a leading vehicle coupled with two or more vehicles obstructing the view to the crosswalk, increased the likelihood that the speed will decrease by at least 1.17 km/h for the Elm/Eagle location, and 1.30 km/h for the Oak/Eagle location, at a higher magnitude when an HVC is installed as compared to when an HVC is absent (in the absence of the HVC the computed likelihood increase is 0.027, whereas in the presence of the HVC it is 0.045).

In addition to the HVC-related variables, a number of other factors were found to affect the likelihood of a statistically significant speed, acceleration and TPA decrease between the benchmark and crosswalk points, and of the brake pedal application. These factors capture or control for socio-demographics (gender, age), vehicle-specific information (type, make year), environmental characteristics (weather, visibility), temporal effects (time of day, season), visibility conditions (obstructing/parked/ leading vehicles, location), and frequent traversal effects (capturing drivers' habitual effects). The effect of these variables on the dependent variables is generally intuitive (note that some of these variables resulted in random parameters, and their effect varies across the observations).

Examining the random parameter linear regression models, and as a result of the findings from the hypothesis tests (Table 5-1), the first set used as dependent variables the change in speed, acceleration, and TPA between the benchmark and crosswalk points, while the second set, estimated separate models of speed, acceleration and TPA at the benchmark and the crosswalk points. Table 5-3 presents the model results.

Table 5-2. Estimation results of the binary mixed logit models (random parameters are shown in italics)

Variable description	Speed decrease	Acceleration decrease	TPA decrease	Brake application
Constant	1.842[a]	*0.298*[b]	0.278[c]	4.881[a]
HVC related variables				
HVC indicator (1 if HVC is present , 0 otherwise)	--	*1.038*[a]	--	--
HVC indicator (1 if HVC and pedestrian sign are present , 0 otherwise)	--	--	--	1.486[a]
HVC indicator (1 if HVC is present and the vehicle exceeds the speed limit at the benchmark point by 5 mph – 8.05 km/h – or more, 0 otherwise)	*0.799*[b]	--	--	--
Obstructing view indicator (1 if HVC is absent and leading vehicle is present and there are 2 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	0.750[a]	--	--	--
Obstructing view indicator (1 if HVC is present and leading vehicle is present and there are 2 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	1.064[a]	--	--	--
Non-HVC related variables				
Speed indicator (1 if the vehicle exceeds the speed limit at the benchmark point by 5 mph – 8.05 km/h – or more, 0 otherwise)	--	*-0.467*[b]	--	--
Obstructing vehicle indicator (1 if leading vehicle is present and there are 2 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	--	--	--	1.873[a]
Parked vehicle indicator (1 if non-passenger car is parked ahead of the crosswalk, 0 otherwise)	*-0.045*[c]	*-0.264*[c]	--	--
Parked vehicle indicator (1 if there is 1 parked vehicle ahead of the crosswalk, 0 otherwise)	--	-1.145[a]	-1.172[a]	--
Weather indicator (1 if weather is clear, 0 otherwise)	--	--	-0.427[b]	--
Windshield condition indicator (1 if visibility through the windshield is good, 0 otherwise)	--	*-0.598*[c]	--	--
Windshield condition indicator (1 if visibility through windshield is very poor, 0 otherwise)	--	--	--	1.028[b]
Wiper indicator (1 if wiper is off, 0 otherwise)	-0.590[c]	--	--	--
Gender indicator (1 if driver is male, 0 otherwise)	0.811[a]	--	--	--
Driver's age indicator (1 if greater than 45 years old, 0 otherwise)	1.003[a]	--	--	--
Make-year of vehicle indicator (1 if 2007 or 2009, 0 otherwise)	0.619[b]	--	--	--
Traversal time indicator (1 if between 6 am to 9 am, 0 otherwise)	-0.705[a]	--	*0.678*[b]	--
Traversal time indicator (1 if between 12 pm to 6 pm, 0 otherwise)	--	--	--	*-0.912*[c]
Frequent traveler indicator (1 if driver traversed more than 20 times the same location, 0 otherwise)	0.469[c]	--	--	--
Frequent traveler indicator (1 if driver traversed 5 times or fewer the same location, 0 otherwise)	--	--	--	2.030[a,d]
Number of drivers/Number of traversals	49/799	49/802	44/746	30/670
Log-likelihood at convergence	-427.4	-471.9	-444.3	-117.5
Restricted Log-likelihood	-553.8	-555.9	-517.1	-464.4

[a]: 0.99 level of confidence; [b]: 0.95 level of confidence; [c]: 0.90 level of confidence

Note that the mean of all dummy variables is between 0.1 and 0.9, with the exception of those marked with [d], which have a mean between 0.07 to 0.10, or 0.90 to 0.93 (representing statistically significant variables with low variance that warrants further investigation). Also note that the standard deviations of the parameter density functions of the random parameters are all statistically significant but are omitted to save space. Finally, the models were estimated through the use of random effects, to account for possible systematic variations (i.e., panel effects) for traversals performed by the same driver and at the same location.

Table 5-3. Estimation results of linear regression models (random parameters are presented in italics)

Variable description	*Speed at BM*	*Speed at HVC*	*Speed diff.*	*Acc at BM*	*Acc at HVC*	*Acc diff.*	*TPA at BM*	*TPA at HVC*	*TPA diff.*
Constant	*53.019*[a]	4.109[c]	*2.662*[a]	*0.009*[b]	*0.011*[b]	0.016[b]	7.039[a]	3.354[c]	-3.140[b]
HVC related variables									
HVC indicator (1 if HVC is present, 0 otherwise)	-2.131[a]	*-2.560*[b]	--	--	-0.009[a]	--	--	--	--
HVC and pedestrian sign indicator (1 if both are present, 0 otherwise)	--	--	-1.008[b]	--	--	-0.016[a]	--	--	--
HVC and speed indicator (1 if HVC is present and the vehicle exceeds the speed limit at the benchmark point by 5 mph – 8.05 km/h – or more, 0 otherwise)	--	8.584[a,d]	--	--	--	--	--	--	--
HVC and pedestrian indicator (1 if both are absent, 0 otherwise)	--	*2.010*[b]	--	--	--	--	4.316[a]	--	--
HVC and pedestrian indicator (1 if HVC is present but pedestrians are absent, 0 otherwise)	--	*0.966*	--	--	--	--	--	--	--
HVC and pedestrian indicator (1 if HVC is absent but pedestrians are present, 0 otherwise)	--	--	--	--	--	--	6.146[a,d]	--	--
HVC and pedestrian indicator (1 if both are present, 0 otherwise)	--	--	--	*-0.019*[a,d]	--	--	-3.501[c,d]	--	--
HVC and visibility indicator (1 if windshield visibility is poor or very poor and HVC is not installed, 0 otherwise)	--	--	--	--	--	--	--	--	-2.673[c]
HVC and visibility indicator (1 if windshield visibility is poor or very poor and HVC is installed, 0 otherwise)	--	--	--	--	--	--	--	--	-3.094[b]
Non-HVC related variables	--	--	--	--	--	--	--	--	--
Speed at benchmark point (km/h)[e]	--	0.930[a]	--	--	--	--	--	--	--
Acceleration at benchmark point (in g)[e]	--	--	--	--	0.258[a]	--	--	--	--
TPA at benchmark point[e]	--	--	--	--	--	--	--	0.320[a]	--
Speed indicator (1 if the vehicle exceeds the speed limit at the benchmark point by 5 mph – 8.05 km/h – or more, 0 otherwise)	--	--	-3.074[a]	-0.022[a]	--	--	-3.098[b]	--	--
Pedestrian indicator (1 if pedestrian is present near the HVC, 0 otherwise)	*-1.540*[c]	--	--	--	--	--	--	--	--
Leading vehicle indicator (1 if leading vehicle is present, 0 otherwise)	--	--	*-1.397*[a]	*-0.015*[a]	--	0.015[a]	-2.704[b]	--	--
Obstructing vehicle indicator (1 if there are 2 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	--	--	--	--	--	--	-3.738[a]	--	2.690[b]
Obstructing vehicle indicator (1 if there are 4 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	--	--	-1.401[a]	--	--	--	--	--	--
Obstructing vehicle indicator (1 if leading vehicle is present and there are 2 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	*-5.950*[a]	--	--	--	--	--	--	--	--
Obstructing vehicle indicator (1 if leading vehicle is present and there are 3 or more vehicles obstructing the view to the crosswalk, 0 otherwise)	--	*-1.005*	--	--	--	--	--	--	--
Parked vehicle indicator (1 if there is a parked vehicle ahead of the crosswalk, 0 otherwise)	*-1.050*	--	--	--	--	--	--	--	--
Parked vehicle indicator (1 if there are 2 or more parked vehicles ahead of the crosswalk, 0 otherwise)	--	-0.660[b]	--	--	--	--	--	--	1.824[c]
Side lane indicator (1 if a vehicle is on the inside lane on a multilane roadway possibly obstructing the crosswalk view, 0 otherwise)	--	--	-0.842[c]	--	--	--	--	--	--
Vehicle type indicator (1 if passenger car, 0 otherwise)	--	--	--	--	--	-0.009[c]	--	3.297[a]	--

Variable description	*Speed at BM*	*Speed at HVC*	*Speed diff.*	*Acc at BM*	*Acc at HVC*	*Acc diff.*	*TPA at BM*	*TPA at HVC*	*TPA diff.*
Vehicle type indicator (1 if pickup truck, 0 otherwise)	--	--	--	--	--	--	-6.131[a,d]	--	--
Make-year of vehicle indicator (1 if before 2009, 0 otherwise)	--	--	--	*0.020*[a]	--	--	--	--	--
Wiper indicator (1 if wiper is off, 0 otherwise)	*1.524*	--	--	--	--	--	--	--	--
Windshield condition indicator (1 if visibility through windshield is very good, 0 otherwise)	--	--	--	--	*0.006*	--	--	--	--
Windshield condition indicator (1 if visibility through windshield is very poor, 0 otherwise)	--	--	--	--	-0.010[b]	-0.017[a]	--	--	--
Weather indicator (1 if weather is cloudy, 0 otherwise)	*-0.557*	--	--	--	--	--	--	--	--
Weather indicator (1 if weather is rainy or snowy, 0 otherwise)	--	--	--	--	--	-0.013[b]	--	--	-2.585[c]
Gender indicator (1 if driver is female, 0 otherwise)	*2.833*[a]	--	--	--	*-0.011*[a]	--	--	--	--
Driver's age indicator (1 if 30 years old or less, 0 otherwise)	--	2.414[a]	--	0.014[a]	--	-0.014[a]	5.071[a]	--	--
Driver's age indicator (1 if greater than 45 years old, 0 otherwise)	*-3.785*[a]	--	--	--	--	--	--	-4.264[a]	--
Driver's age indicator (1 if greater than 50 years old, 0 otherwise)	--	--	--		--	--	--	--	2.238[b]
Driver's age indicator (1 if greater than 60 years old, 0 otherwise)	--	--	-0.816[c]		--	--	--	--	--
Season indicator (1 if traversal occurred between Aug. and Oct., 0 otherwise)	--	--	--	--	--	--	2.170[b]	--	--
Season indicator (1 if traversal occurred between Dec. and Feb., 0 otherwise)	--	--	--	--	--	0.016[a]	--	--	4.167[a]
Day indicator (1 if traversal occurred over the weekend, 0 otherwise)	*2.222*[a]	--	--	--	--	--	--	1.841[c]	--
Time indicator (1 if traversal occurred between 6 am and 9 am, 0 otherwise)	--	--	*1.209*[a]	--	--	-0.018[a]	--	--	-3.698[a]
Time indicator (1 if traversal occurred between 9 pm and 12 pm, 0 otherwise)	--	--	--	--	--	--	-5.853[a,d]	--	--
Lighting indicator (1 if traversal occurred at dawn or dusk, 0 otherwise)	--	--	--	--	--	-0.015[a]	--	--	--
Lighting indicator (1 if traversal occurred at night, 0 otherwise)	--	--	--	-0.014[c]	--	--	--	--	--
Frequent traveler indicator (1 if driver traversed more than 5 times the same location, 0 otherwise)	--	--	--	--	0.009[b]	--	6.015[a]	3.378[b]	--
Frequent traveler indicator (1 if driver traversed more than 20 times the same location, 0 otherwise)	--	*-1.493*[a]	--	--	--	--	--	--	--
Frequent traveler indicator (1 if driver traversed more than 50 times the same location, 0 otherwise)	--	--	2.392[a]	--	--	--	--	--	--
Frequent traveler indicator (1 if driver traversed between 6 and 10 times, 0 otherwise)	--	--	--	*0.021*[a,d]	--	--	--	--	--
Location indicator (1 if Hamburg location, 0 otherwise)	--	--	-1.380[b]	--	--	0.023[a]	--	--	3.270[b]
Variance parameter, sigma	6.832[a]	6.383[a]	4.482[a]	0.053[a]	0.042[a]	--	--	--	--
Number of drivers/Number of traversals	62/1074	62/1074	62/1078	62/1078	62/1078	62/1078	57/1001	57/1001	57/1001
Log-likelihood at convergence	-3681.1	-3540.2	-3137.5	1699.9	1883.2	1437.3	-4150.8	-3952.4	-4200.7
Restricted Log-likelihood	-4083.1	-4137.5	-3354.2	1504.4	1815.5	1379.4	-4208.1	-3991.3	-4223.2

[a]: 0.99 level of confidence; [b]: 0.95 level of confidence; [c]: 0.90 level of confidence; BM: Benchmark point; HVC: High visibility crosswalk (referring to the crosswalk point); diff.: Value difference between the benchmark and crosswalk points

Note that the mean of all dummy variables is between 0.1 and 0.9, with the exception of those marked with [d], which have a mean between 0.07 to 0.10, or 0.90 to 0.93 (representing statistically significant variables with low variance that warrants further investigation). Also note that the standard deviations of the parameter density functions of the random parameters are all statistically significant but are omitted to save space. Finally, the models were estimated through the use of random effects, to account for possible systematic variations (i.e., panel effects) for traversals performed by the same driver and/or at the same location.

Table 5-3 shows that the HVC related variables affected speed, acceleration and TPA (the observed values at and their difference between the benchmark and crosswalk points) in most of the models. For example, the presence of the HVC decreased the speed at the benchmark and crosswalk points, and also decreased the acceleration at the crosswalk point. The HVC presence combined with the pedestrian crossing sign, decreased both the speed and acceleration difference from the benchmark to the crosswalk point. Also, if the HVC was installed and the vehicle exceeded the speed limit at the benchmark point by at least 5 mph (i.e., 8.05 km/h), the speed at the crosswalk point increased. This low-variance variable (the mean of this dummy was about 0.07, reflecting only 7 percent of the observations) is possibly picking up the speeding effect rather than the effect of the HVC, and naturally warrants further investigation.

Furthermore, pedestrian presence and HVC absence increased the TPA at the benchmark point, whereas, both HVC and pedestrian presence decreased the TPA. In the cases that there were no pedestrians nearby, the speed at the HVC location increased regardless of the HVC presence, but the speed increase was less after the HVC was installed. This is an indication that the HVC installation contributed to a lower speed increase rate.

Interestingly, poor or very poor windshield visibility decreased the TPA difference between the benchmark and crosswalk points at a lower rate when the HVC was installed, as compared to before the HVC installation. This indicates that the presence of the HVC possibly alerted the drivers, who in turn decreased their pressure on the throttle.

In addition to the HVC-related variables, a number of other factors were found to affect the nine linear dependent variables in Table 5-3. These factors capture or control for socio-demographics (gender, age), vehicle-specific information (type, make, year), environmental characteristics (weather, visibility), temporal effect (time of the day, season), on site condition (obstructing /parked / leading vehicles, location), and frequent traversal effects. The effect of these variables on the dependent variables is generally intuitive (note that some of these variables resulted in random parameters, and their effect varies across the observations). It should be noted that the inclusion of driver socio-demographic parameters is a unique advantage of use of SHRP2 NDS data.

Finally, for the speed, acceleration, and TPA at the crosswalk point, the respective variables at the benchmark point were used as explanatory parameters, which inevitably introduced endogeneity. This misspecification issue was treated by regressing the endogenous variables against all exogenous variables, and using their predictors for model estimation.

6. Future Direction

6.1 The Phase 2 Research Aligns With the Safety Task Force (STF) Focus Areas

Our proposed Phase 2 program will provide new insights into the effectiveness of HVCs to improve pedestrian safety at uncontrolled crossing locations. As noted in Table 6-1, our proposed Phase 2 research has a primary focus consistent with three of the five STF focus areas. It also has a secondary focus with the Driver Speed area.

Table 6-1 Relationship of Phase 2 Focus with Safety Task Force Focus Areas

Safety Task Force Focus Areas	Focus of Phase 2 Research	Comments
1. Driver Speed	Secondary Focus	Phase 2 will examine driver speed during intersection transversals with and without pedestrians and with and without HVC markings and crossing signage.
2. Roadway Features & Driver Performance	Primary Focus	Phase 2 will examine the effectiveness of various HVC designs and signage in modifying driver behavior.
3. Preceding Contributory Events	-	-
4. Vulnerable Road Users	Primary Focus	Phase 2 will address pedestrians crossing roadways at uncontrolled intersections and mid-block locations
5. Intersections	Primary Focus	Phase 2 will examine driver behavior in the presence and absence of pedestrians at both urban and suburban uncontrolled intersections.

6.2 Phase 2 will Provide New Insights into HVC Effectiveness

In Phase 1 we demonstrated the feasibility of our research methodology to analyze the effectiveness of HVCs to improve pedestrian safety using a relatively small sample of the available the SHRP2 NDS and RID data. The small data sample resulted in a number of limitations (e.g., low variance of some explanatory parameters, small pedestrian presence, missing data in available variables, and so on). Phase 1 also revealed there were also no vehicle-pedestrian conflicts in the Erie County SHRP2 study site, possibly due to the very small number of observations explored. During Phase 2 we will expand the analyses by identifying, accessing, and utilizing intersection traversal data from all six SHRP2 NDS test sites. This will permit us to provide robust results, including additional measures of effectiveness (e.g., vehicle-pedestrian conflicts). In addition to answering the general question of HVC effectiveness in improving pedestrian safety, the availability of data from the six NDS test sites will allow us to address the following questions:

- Are there differences in effectiveness between mid-block and end block uncontrolled HVCs?
- How do different HVC marking designs (e.g., basic, continental HVC, ladder HVC, bar pair HVC, diagonal HVC markings, etc.), and signage affect HVC effectiveness?
- Are there differences in effectiveness due to regional variations in driver behavior?

We do not anticipate that novel pedestrian safety countermeasures will be produced during the Phase 2 program. However, we do expect that the research will provide clear measures of the effectiveness (or lack of effectiveness) of various HVC designs in improving pedestrian safety. We anticipate these results will be of great use to local and state agencies in deciding where and how to allocate available safety-related resources.

6.3 Phase 2 Results are Likely to Result in Implementation of Safety Improvements

Although we cannot anticipate the final results of the Phase 2 program research, we do expect the program to provide robust results quantifying the effectiveness of HVCs in improving pedestrian safety. These results will be very useful in developing strategies to implement safety countermeasures.

The results from this study will be especially timely for New York State. Currently the New York State DOT is coordinating with safety partners from the Governor's Traffic Safety Committee, the NYS Department of Health, FHWA, Metropolitan Planning Organizations, and local transportation agencies to develop a Pedestrian Safety Action Plan (PSAP). Strategies in the plan include enforcement, education and engineering actions with the goal to significantly reduce pedestrian crashes in New York.

The package of engineering measures outlined in the PSAP includes systemic treatments at locations that contain risk factors associated with pedestrian crashes. Over a five year period (2016-2020), NYSDOT plans to install HVC markings at all existing uncontrolled crosswalks and at signalized intersections for state maintained facilities. The completion of this research will help to ensure NYSDOT uses the most effective design for these crossings for both the markings as well as other elements such as warning sign placement. In addition, many of the pedestrian crashes in NYS occur "off-system" – on roadways maintained by local jurisdictions. The results of this research will assist the NYSDOT in demonstrating to local agencies the benefits of using HVC markings, even though the cost to install and maintain may be higher. A portion of the state's Highway Safety Improvement Program funding will support these local projects.

7. Phase 2 Proposal

We propose to conduct the Phase 2 effort with the same NYS DOT, CUBRC and UB team and staff that was used in Phase 1. The following sections provide information on the Phase 2 data needs, methodology/tasks, schedule and cost.

7.1 Data Needs

Our proposed Phase 2 effort will build upon the experience and lessons learned during the successful Phase 1 effort. We anticipate using the same strategy for requesting both RID and SHRP2 NDS data. The data request process is shown in Figure 7-1 and includes the following steps:

- Identify crosswalks of interest at all six SHRP2 NDS study center sites
- Obtain roadway feature data and links defining HVC traversals from the RID database
- Request trip information from the SHRP2 NDS database. Use the trip information to select and request time series and forward video data for use in the analysis and modeling tasks. As in Phase 1, we anticipate the selection of trips of interest and the requests for time series and video data will be an iterative process (shown by the dashed lines).

We intend to utilize the same time series data elements, forward looking video data and RID data elements that we used in Phase 1. During Phase 1 we found the 'Steering Wheel Angle' and

‘Brake Pedal State’ data elements we requested were not consistently available in trip data files. In Phase 1 we acquired the ‘Acceleration – x axis’ data element. This allows us to evaluate the brake pedal status should the ‘Brake Pedal State’ data element not be available.

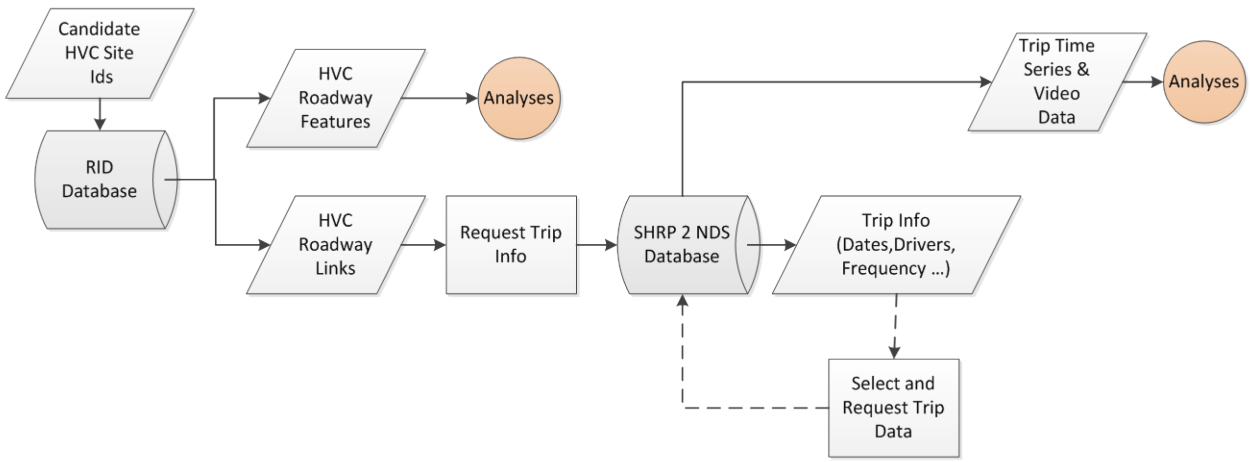


Figure 7-1 Data Acquisition Strategy

In Phase 2, we plan to request two additional time series data elements, namely: ‘Acceleration y-axis’, and ‘Rate gyro z-axis’. These two data elements will enable us to evaluate the ‘Steering Wheel Angle’ should that data element not be available. Finally, we plan to evaluate the availability and utility of ‘Eye Glance’ information. Preliminary discussions with VTTI indicate they may be able to process the driver face video and provide eye glance information. If available, the processed video would not contain any Personally Identified Information (PII), thus none of the required Phase 2 data will involve PII.

7.2 Research Approach, Methods and Tasks

The Phase 1 effort demonstrated the availability of crosswalk intersections and New York test site NDS driving data required to support the HVC effectiveness analyses. In Phase 2 we will expand the scope of the effort to study intersections with and without HVC marking at locations in the other five NDS test sites. As noted in Section 5, this will increase the number of traversals available for analysis as well as expand the research questions we plan to address.

The Phase 2 research approach, methods and tasks will be similar to those followed in Phase 1. The discussion below provides a brief summary of the seven tasks and highlights any differences between the Phase 1 and Phase 2 tasks.

Task 1: Develop a Research Plan

As in Phase 1 we plan to develop a Research Plan to guide the technical work to be performed during the project. The plan will describe the program objectives and Statement of Work (SOW), and the strategies we will employ in the analyses. In addition, the plan will incorporate any comments and suggestions provided by FHWA/AASHTO during the project ‘kick-off’ discussions.

Task 2: Acquire IRB Approval

We will apply for approval for our Phase 2 program from the SUNY at Buffalo Social and Behavioral Sciences (SBS) IRB. The UB SBS IRB has an approved Federal Wide Assurance Number (IRB00003128) on file with the Department of Health and Human Services and is fully accredited by the Association for the Accreditation of Human Research Protection Programs. We do not anticipate any problems obtaining IRB approval since our Phase 1 effort acquired approval and we are not requesting any PII information for the Phase 2 program.

Task 3: Select Intersections and Acquire Data

As noted in Table 7-1, we have already identified 22 candidate uncontrolled crosswalk locations with HVC markings in the FL, WA, IN and NC SHRP2 NDS test sites. These locations provide a sample of the various HVC markings currently in use (i.e., continental, zebra and ladder). In this task we will coordinate with state DOTs in these test sites to identify additional crosswalks and acquire information on all locations so that we can generate a prioritized list of study crosswalks. Of particular interest will be HVCs that were installed between January 1, 2010 and March 31, 2013. The prioritized list of crosswalks will be used to initiate requests for data from VTTI. Steps in this process include developing a Data Specification, required by VTTI to permit the delivery of a cost quotation, and a Data Sharing Agreement (DSA). With these documents in place VTTI will be able to provide listings of traversals through the selected locations. As was the case in Phase 1 an iterative process will be used to request NDS data elements from VTTI.

Table 7-1 Selected HVC Sites Located Within SHRP2 NDS Study Centers

NDS Site	Location	HVC Markings Design	No. of Traffic Lanes	Median Present	Posted Speed Limit	AADT	No. Of Trips Thru HVC	No. of Drivers Thru HVC
FL	S. Miller Rd, Citrus Wood	Zebra	2	No	40/20*		1,850	57
FL	S. 78th St, Progress Village	Continental	2	No	45	3,300	274	28
FL	North Boulevard, Tampa	Ladder	2	No	30	900	1,519	139
FL	N. 40th Street, Tampa	Continental	2	No	40	19,400	935	129
FL	Telfair Rd, Tampa	Ladder	2	No	30		251	19
FL	W. Snow St, Tampa	Continental	2	Yes	25	4,800	763	63
FL	S. Howard Ave, Tampa	Continental	2	No	30	9,500	1,170	94
WA	NE 65th St, Seattle	Continental	2	No	30		1,354	102
WA	E. Green Lake Way N, Seattle	Continental	2	No	30		1,144	167
WA	Phinney Ave N, Seattle	Continental	3	No	30		752	74
WA	NE Pacific St, Seattle	Continental	2	No	30		921	143
WA	116 Ave SE, Seattle	Continental	3	No	30		525	37
WA	E. Pike & Belmont Ave, Seattle	Continental	2	No	30		496	159
WA	Ravenna Ave NE & NE 82nd St, Seattle	Continental	2	No	30		1,247	119
NC	W. Rosemary St, Chapel Hill	Ladder	2	No	25		1,794	102
NC	W Cameron Ave, Chapel Hill	Ladder	2	No	25		1,222	67
NC	S. Greensboro St, Chapel Hill	Continental	2	No	20	12,000	2,414	99
NC	E. Cameron Ave, Chapel Hill	Continental	2	No	25		904	101
NC	Blackwell St, Durham	Continental	2	No	25		379	109
NC	E Morgan St, Durham	Continental	3	No	25	5,800	677	112
IN	N Fee Lane, Bloomington	Continental	2	Yes	35		1,908	137
IN	Countryside Lane, Bloomington	Continental	2	No	30/20*		592	28

Task 4: Process Acquired Data – Develop Research Database

We plan to review all received time series and forward-looking video data for completeness and consistency. Time series trip data that does not contain essential data elements will be excluded from the Research Database and the video data will be reviewed and coded. In addition, we will review the available eye glance data to determine if there is useful information to permit the analysis of driver recognition of the presence of HVC markings, signage, and pedestrian presence. Finally, we will compile the time series, coded video, eye glance data, and participant data into a Research Database to support the analysis and modeling activities to be conducted in Task 5.

Task 5: Perform Analysis

The principal focus of the analysis task will be to develop statistical models that control for a variety of factors, including: roadway geometric characteristics; traffic characteristics; day, month, time, and year of the trips; pedestrian presence; lighting conditions; pavement conditions; weather conditions; driver demographic and personality characteristics; and vehicle features. These models will provide the true effect of the HVC's on driver and pedestrian safety. We anticipate utilizing the same analysis methodologies successfully employed in the Phase 1 project.

Task 6: HVC Effectiveness and Implementation Strategy

This task will summarize the results of the analyses on HVC effectiveness. Using the Phase 2 research results, guidance and recommendations for HVC implementation strategies will be provided to agencies responsible for highway safety. The recommendations will be provided in written reports as well as oral presentations.

Task 7: Program Management and Accounting

This task will ensure the proper management of program technical tasks and resources. Program management will be accomplished by tracking technical progress against planned milestones, spending profiles and schedule. An important aspect of the management strategy is to provide interim reports documenting progress achieved on the program as well as any issues that may arise.

7.4 Schedule and Milestones

We propose a period of performance for this project of 24 months. Figure A-2 in Appendix A presents a schedule of tasks and milestones.

7.5 Approach to Maintaining Data Security

As noted earlier, we do not anticipate using any PII data. Nevertheless, there is a need to protect all data received from unauthorized access, distribution, or use. As in Phase 1, we will abide by the conditions identified in the Data Use Agreement with VTTI and ensure all staff with access to the data have been trained in human subject research protocols. In addition, we will restrict the data to computers within areas of controlled access at our team's facilities.

7.6 Risk Identification and Risk Mitigation

Table 7-2 identifies the potential risk and risk mitigation strategies we have identified for the Phase 2 program based upon our Phase 1 effort and our overall experience with the SHRP2 NDS data. As noted, the majority of the risk areas relate to insufficient data. Our experience in Phase 1 with the Erie County test site indicates that this poses only a minimal risk to the Phase 2 effort.

Table 7-2 Risk Areas and Risk Mitigation Strategies

Risk Area	Risk Mitigation Strategy
Insufficient number of uncontrolled intersections with HVCs in the SHRP2 NDS test sites to support the analyses	We have already identified a number of HVCs in the FL, NC, IN and WA NDS Sites. We are confident that a sufficient number of locations with HVCs can be identified in the SHRP2 NDS test sites.
Insufficient number of HVC's installed during NDS to support before/after analysis methodology	Although we have identified a number of additional HVC locations for Phase 2 we have not yet established the time they were installed. If we are unable to identify sufficient HVCs installed during the NDS time period we will utilize an experiment/control HVC strategy to determine the HVC effectiveness
Insufficient number of trips through the HVC locations to support statistically significant results	We have reviewed the VTTI InSight Website Travel Density Maps ("Heat Maps") and determined that the numbers of trips through the identified intersections in other test sites are comparable to the numbers of trips observed in the Erie County NY test site.
Missing vehicle data that prevents implementation of our analysis methodology	During Phase1 we utilized only vehicles categorized as "Prime" or "Sub-Prime". This provided us with the most data-rich vehicles for vehicle control inputs. Upon receiving the data in Phase 1 we noted that some data from the controls – such as steering wheel angle, were routinely missing from the time-series data. With this in mind we have revised our data request and have included additional data elements that substitute for any missing vehicle network control data.

8.0 References

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Appendix A

Supplementary Phase 2 Cost and Schedule Information

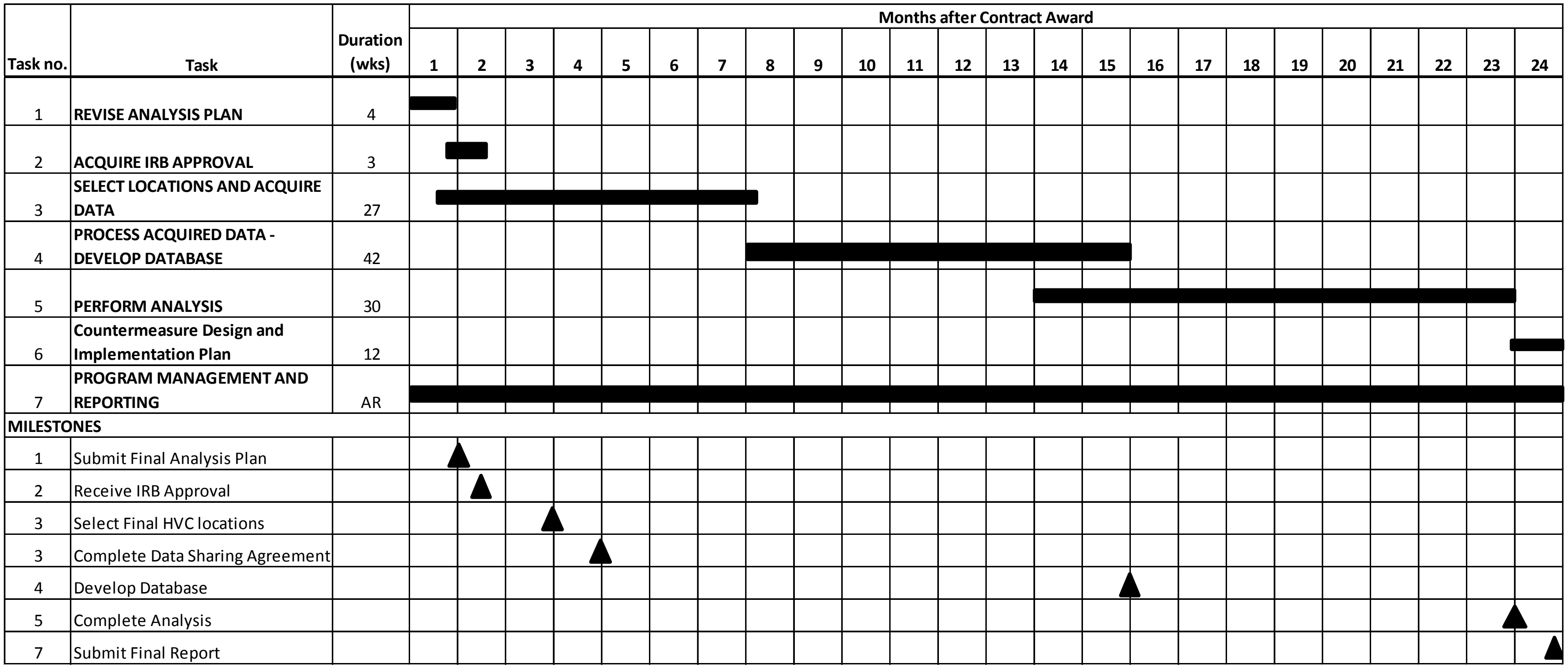

Figure A-2 Phase 2 Schedule and Milestones