A PROFILING BASED APPROACH TO SAFETY SURROGATE DATA COLLECTION

Lakshmi N. Peesapati
Georgia Institute of Technology
School of Civil and Environmental Engineering
Atlanta, GA 30332-0355
Email: npeesapati3@ gatech.edu

Michael Hunter, Ph.D.
Georgia Institute of Technology
School of Civil and Environmental Engineering
Atlanta, GA 30332-0355
Email: michael.hunter@ce.gatech.edu

Michael Rodgers, Ph.D.
Georgia Institute of Technology
School of Civil and Environmental Engineering
Atlanta, GA 30332-0355
Email: michael.rodgers@ce.gatech.edu

Angshuman Guin, Ph.D.
Georgia Institute of Technology
School of Civil and Environmental Engineering
Atlanta, GA 30332-0355
Email: angshuman.guin@ce.gatech.edu

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ABSTRACT

This study identifies the challenges and requirements for a surrogate safety data collection system and provides a robust methodology for surrogate safety data collection. The current study develops a comprehensive methodology for obtaining objective and detailed vehicle profile data from video. This data is used to generate surrogate measures that may be employed for the evaluation of potential safety benefits of improvement strategies at an intersection.

Methods for the collection of three surrogate safety measures have been developed and evaluated in this research: Acceleration-Deceleration profiles, Post Encroachment Time (PET), and intersection approach speed. A custom semi-manual video processing software is developed for the purpose of efficiently reducing the video to a useable format ready for analysis. This semi-manual approach allows for the use of lower camera angles with larger perspective views thereby

limiting equipment needs, a limitation of most of the automatic video detection equipment based approaches. Video recording is at 30 hz resulting in the generation of discrete position-time trajectory data. This process of generating discrete data and the error inherent in manually identifying the key frames required in the data reduction method causes noise in the data. Hence, low pass filters are developed to smooth the noise in the speed and acceleration-deceleration data of sampled vehicles.

To demonstrate the developed methodologies the results for a high speed rural intersection in North Georgia are presented. The video reduction methodology and smoothing algorithms are validated with vehicle traces from global positioning system (GPS) instrumented vehicles. Sampling guidelines are also presented to minimize the required manual effort to reduced the video and determine representative surrogate measures.

Keywords: surrogate, methodology, profile, smoothing, GPS

INTRODUCTION AND BACKGROUND

Traditionally, transportation safety analysis has used vehicle crash data even though these data have limitations with respect to time and accuracy. The use of surrogate safety measures potentially allows for an earlier treatment assessment relative to crash data.

Speed is one of the earliest recognized factors affecting safety. According to Haddon (1972), the relationship between speed and safety can be divided into two terms, one related to a "pre-event" phase and the other related to an "event" phase. The pre-event phase examines how speed affects the probability of the accident and the event phase examines its severity. Since speed may influence each of these factors (Solomon (1964)), it might be considered a surrogate measure for safety. Whether speed can be considered a surrogate measure for safety remains a matter of debate. A white paper on surrogate measures of safety (Tarko et al. (2009)) argues that since crashes are measured in terms of a frequency, an effective surrogate would also be an event whose frequency would be a measure of safety. Speed itself is not a frequency measure and hence it may be difficult to associate a change in speed to a change in crash frequency. However, measures such as number of vehicles traveling above a certain speed, number of speeding tickets etc. might be considered as surrogates if sufficient correlation with crash frequency can be found.

Another indirect safety measurement technique which has been in practice since the 1960s is the Traffic Conflict Technique (TCT) and much of the literature available to date focuses on the use of traffic conflicts as surrogate safety measures (Perkins and Harris, 1967; Sayed and Zein, 1999; Parker and Zegeer, 1989; Hyden, 1987). A conflict is an interaction between two vehicles which would lead to an accident if neither of the vehicles takes evasive action or if the evasive action is insufficient. Over the past several decades researchers have tried to identify indicators of the frequency of conflicts as surrogates for safety. Some of the various surrogate safety measures used in previous studies or mentioned in the literature are:

- Braking or maneuvering (Perkins and Harris (1967)).

- Gap Time (GT) - Time interval between completion of encroachment by turning vehicle and the arrival time of crossing vehicle if they continue with same speed and path (Allen et al., 1978; Gettman et al., 2009).
- Post Encroachment Time (PET) - Time interval between end of encroachment of turning vehicle and the time at which the through vehicle actually arrives at the potential point of collision (Allen et al. (1978)).
- Deceleration Rate (DR) - Rate at which crossing vehicle must decelerate to avoid collision (Cooper and Ferguson, 1976; Gettman et al., 2009).
- Encroachment Time (ET) - Time duration during which the turning vehicle infringes upon the right-of-way of through vehicle (Allen et al. (1978)).
- Proportion of stopping distance (PSD) - Ratio of distance available to maneuver to the distance remaining to the projected location of collision (Gettman et al. (2009)).
- Critical events, e.g., aggressive lane merging, speeding, and running on red (Porter et al., 1999; Sattari and Powell, 1987)
- Acceleration Noise (Sattari and Powell. (1987)).
- Time To Collision (TTC) – Time that remains until the two vehicles would collide if they remain on the same path and speed difference (Hayward, 1972; Hyden, 1987; Hyden, 1996).
- Time Exposed Time To Collision (TET) – Length of time a TTC event remains below threshold (Minderhoud and Bovy (2001)).
- Time Integrated Time To Collision (TIT) – Integral of the TTC-profile during the time it is below threshold (Minderhoud and Bovy (2001)).

Data collection methodologies play an important role in the quality of data obtained and also determine the amount of time and resources required for the data collection effort. For instance, braking and maneuvering are evasive actions taken by the drivers to avoid collisions and are some of earliest considered potential surrogates. Traffic Conflict Techniques (TCT), the methodologies to collect such data, were originally developed in the 1960s (Perkins and Harris (1967)) and are still in use today. An advantage of such techniques is that the conflicts can be detected in the field and in real time. However, these methods require manual recognition and judgment which is inherently a subjective process. Thus, measures such as, TTC, ET, PET, GT, etc. have been developed and utilized as they either do not involve manual judgment or they can be obtained from the post processing of video data (Gettman et al. (2009)).

For example, Sattari and Powell (1987) considered acceleration noise and the mean velocity gradient as potential safety indicators. In this study an onboard servo-accelerometer was used to collect field data, but there were only eight sample profiles collected due to difficulties in measurement. Minderhoud and Bovy (2001) proposed time exposed TTC and time-integrated TTC, attempting to estimate these surrogates using microscopic simulation models. The potential to derive various surrogate measures of safety from existing simulation models has also been investigated in a FHWA study (Gettman et al. (2009)). An underlying challenge to simulation based surrogate measure approaches is the accuracy of the simulation models in replicating actual vehicle behaviors.

Another challenge to some conflict analysis approaches, such as TTC, PET and GT is that while they may allow for an estimation of the probability of collisions (or frequency of collisions); they do not represent the severity of collisions as severity depends in part on speed (Gettman et al., 2003; Kruysse, 1991). Further, they provide only an instantaneous value of the measure for an interaction. However, measures such as speed profile, deceleration rate profile, time-integrated-TTC and extended TTC give a profile of the maneuvering vehicle for every instant of the time period over which the corresponding vehicles interact. A measure such as deceleration rate takes into account both speed and time and therefore may aid in determining both the probability and severity of crashes. Unfortunately, in-field data collection of such surrogate measures is rarely considered given the difficulty and data intense nature of these approaches.

Recent advancements in automatic video and image processing technology offer the promise of efficient and economical surrogate safety data collection while reducing uncertainty associated due to human interpretation and subjectivity. Such technology has paved the way for automated detection of vehicles and their motion (Kanhere et al., 2006; Chin et al., 1992) and research is ongoing on the use of computer vision technology to determine various traffic parameters (Beymer et al., 1997; Vasquez and Fraichard, 2004) and to issue warnings about imminent collisions in real-time (Atev et al., 2005; Messelodi and Modena, 2005). Imaging technology has also been used in detection of conflicts (Saunier and Sayed (2007)) for vehicle speed (using a larger detection zone) and a few surrogate measures such Post Encroachment Time (PET) and Gap Time. However, such methods have not been validated (Songchitruksa and Tarko (2004)).

Songchitruksa and Tarko (2004) suggests that further research is needed for handling intersections and cases which involve multiple cameras. The Next Generation Simulation (NGSIM) software from Cambridge Systematics, Inc extracts vehicle positions from video obtained from multiple cameras and translates this data into vehicle trajectories (NGSIM (2006)). However, these and similar approaches have limitations in terms of the camera interface requirements such as resolution, camera angle, bit rate, etc., which limit their usage. For example, studies utilizing temporary equipment installations often are required to cover large areas with a limited number of cameras. This requirement mandates low camera angles that are incompatible with the existing automated vehicle profile detection methodologies. The research reported here is an effort to overcome some of these limitations.

METHODOLOGY

Experiment Objective

The focus of this research is development of a semi-automated data collection methodology that more readily allows for in-field measurement of profile-based surrogate measures, such as, speed and deceleration rate. Software has been developed for the purpose of efficiently reducing video using a combination of automation and manual interaction. Post-processing and analysis of the video produces time and position data for each vehicle. The speed, acceleration/deceleration profiles of the vehicles may then be calculated from the developed time-space profiles.

This methodology was developed and evaluated as part of the initial phase of an evaluation of the effectiveness of safety treatments (non-standard striping - a combination of 3 chevron stripes 1000 ft upstream of the intersection and 3 stripes preceding the stop bar to serve as graduated stop bars) at the intersection of US23/SR 365 and Demorest Mt Airy Highway (CR387) in

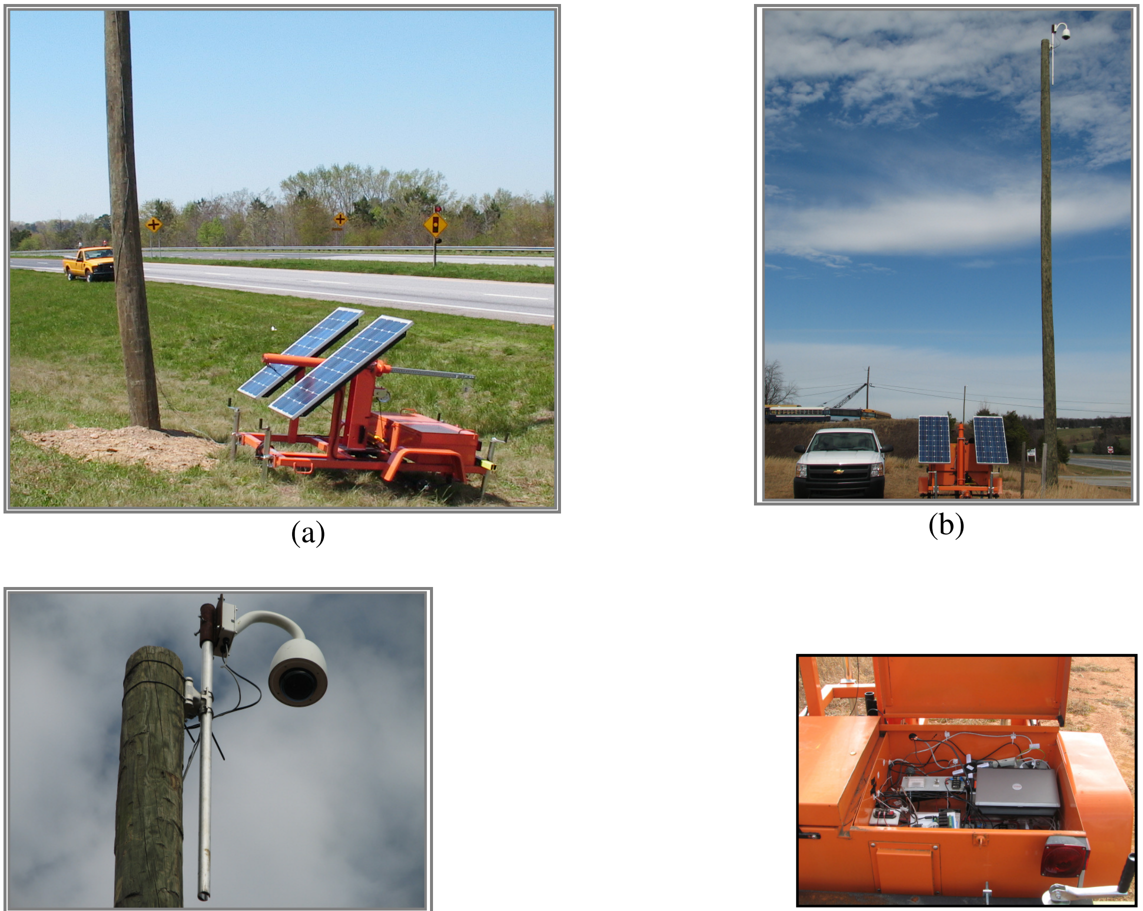
Habersham County, Georgia (Figure 1). The proposed safety treatments were aimed at addressing the conflict between a left-turn vehicle and the opposing through vehicle on this high-speed rural highway. Based on the conflict considered for this overall study, the methodology was design to capture the following surrogate measures, which were considered pertinent:

(a) Acceleration and Deceleration Profiles
(b) Post Encroachment Time
(c) Intersection approach speed

Figure 1 Study area

In-Field Equipment

Video data used in the study were collected using a portable data collection stations developed for this purpose (Figure 2). The recorded videos had a frame rate of 30 frames per second with a resolution of 740x480 pixels. Each portable station consists of a trailer equipped with solar panels that charge a set of six deep cycle marine batteries which supply a constant 12Volt DC power. The data collection unit is equipped with a pan-tilt-zoom (PTZ) network camera that can either be mounted on the mast of the trailer or mounted on a separate pole adjacent to the trailer. The use of a network camera, instead of an analog camera, allows for a direct connection of the camera to a low power notebook computer. The video stream is recorded on the notebook and periodically exported to an external hard drive. The setup also features a wireless cellular network connection that allows a user to remotely control the camera (change the view, turn off/on etc.) as well as control the recording process. The video data collection station is designed to provide high flexibility in the communication, recording, and camera control processes on a low power budget, allowing solar panels to act as the primary external charging source for an extended period.



(a) (b)

(d) (c)

Figure 2 Example data collection unit (a) Equipment trailer at base of pole, (b) Pole and the camera mounted on it, (c) Trailer on-board equipment, and (d) Closer view of the camera

Field Deployment

The study intersections are on a high-speed rural multilane highway with a speed limit of 65 mph (104.5 km/h). The length of the intersection approach covered by the video is approximately 900 feet (274.32 m). This distance was selected to exceed the distance required for a vehicle to stop based on stopping sight distance criteria for the given speed limit. For this research effort the cameras are mounted on wooden poles at a height of approximately 45'. Given the video coverage area and camera heights, a single camera was found to be insufficient to cover the entire 900' study zone. In order to cover the entire area of interest two cameras and portable data collection units are utilized, each viewing approximately half of the approach length. The camera views were sufficiently overlapped to enable accurate vehicle re-identification and video synchronization during the post-processing of the multiple camera views.

Data Reduction Software Design

Custom software was developed using Java™ and using the Java Media Framework (JMF) to allow for a frame-by-frame review of the video. For any frame selected by an analyst, the software may be used to extract the frame number and timestamp. The custom software has two primary components – SaveGrid and ExtractData. SaveGrid allows the analyst to construct a video overlay containing detection lines separated by a set distance, 40ft in this effort, based on known locations in the field of view. In this effort the known points were determined as part of the initial field survey during the in-field equipment setup. The overlay is saved and is later re-loaded in the ExtractData module for extraction of data from the video. The red detection lines in Figure 3 represent a typical video overlay.

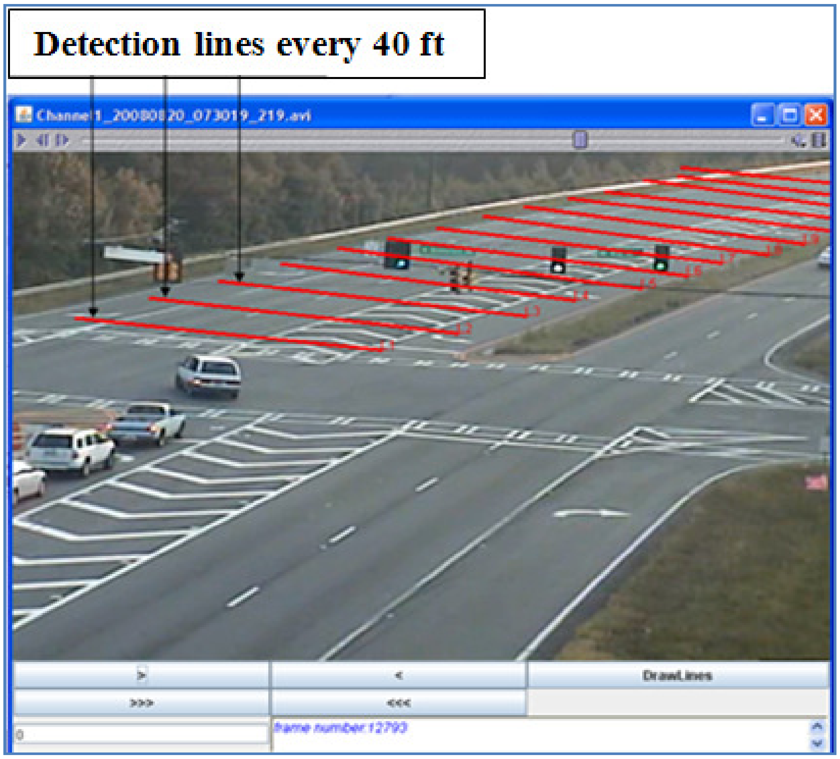
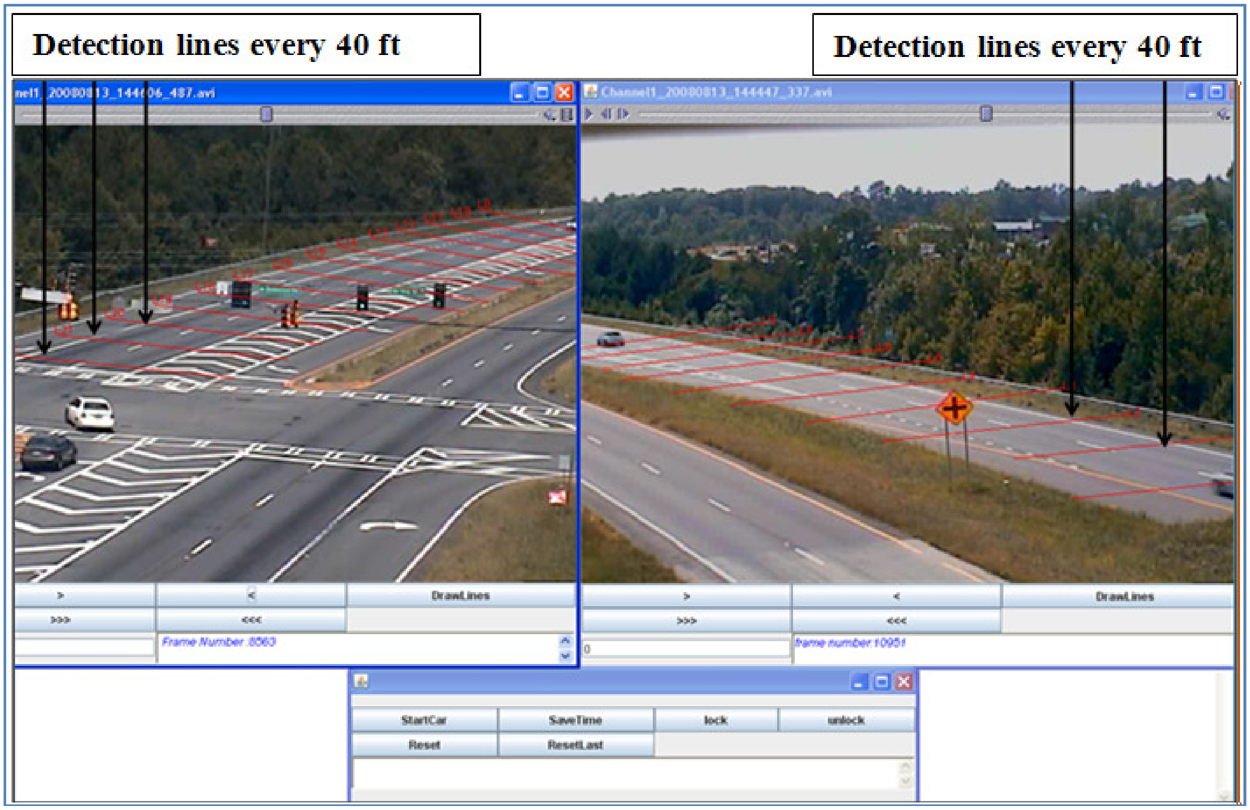


Figure 3 Example screenshot of video reduction software

ExtractData is used to collect the data from the video. A frame of the ExtractData component is shown in Figure 4. The software allows the data analyst to step through the video frame-by-frame (both forward and reverse) as well as by a customizable multi-frame step for faster navigation. At the start of data reduction the analyst will import the overlay detection lines created from the SaveGrid component. The analyst may then extract the time and position data of each vehicle as it crosses each detection line drawn in the video overlay. Using frame-by-frame (or multi-frame) to step through the video the analyst selects the frame in which the front tires of the vehicle, for which data is being collected, is positioned on the detection line of interest in the video. The analyst then selects the "Savetime" button. On doing so the distance of the vehicle from the stop bar (given by the overlay detection line number), the corresponding frame number, and the timestamp are recorded. The analyst also has several reset options to aid in handling analyst errors (such as saving the information for the incorrect frame or skipping a detection line while processing a vehicle). To minimize errors the analysts tracks one vehicle through the entire intersection approach prior to collecting data for the next vehicle. All data for a video is stored in a comma-separated-value (CSV) ASCII file.



(a) (b)

Figure 4 Example approach camera views using two cameras: (a) View of upstream portion of appraoch, and (b) Example of downstream portion of approach.

As stated previously, two cameras are used to capture each intersection approach. To process the vehicles, the video from the two cameras must be synchronized. Figure 4 provides an example of the video from two cameras for an approach. Figure 4a shows the downstream portion of the approach (i.e. the portion closest to the intersection) and Figure 4b shows the upstream portion of the same approach. Note that in this example the viewing angles are not from the same direction, that is, the upstream is viewed from the South end while the downstream is viewed from the North end. The top right corner in Figure 4a and the top left corner in Figure 4b constitute the region of overlap.

The videos are initially synchronized by manually matching the position of a test vehicle in the two videos at an overlapping detection line, i.e., a set distance from the intersection captured in both videos. Once the videos have been synchronized, the ExtractData software component allows the analyst to lock the two videos together to step forward/backward synchronously when being reviewed by an analyst. That is, if one video is forwarded by the analyst, the other video is automatically forwarded by the same number of frames. Provision is also made to maintain synchronization through the transition from one video clip to the next since the beginning timestamps of the clips from the two sources are not expected to match exactly.

Additional Data Extraction

The video analysis software is also used to evaluate the Post Encroachment Time (PET). PET refers to the time lapse between the end of encroachment of a turning vehicle and the time when the through vehicle enters the potential area of collision. Since there are two through lanes, there are two areas of conflict. These two areas are marked on the videos using the SaveGrid software component prior to starting the analysis. Next, using the ExtractData software component the analyst extracts the time stamps of the end of encroachment of left turning vehicle and the time of arrival of the through vehicle at the area of conflict. The difference between these timestamps is the PET.

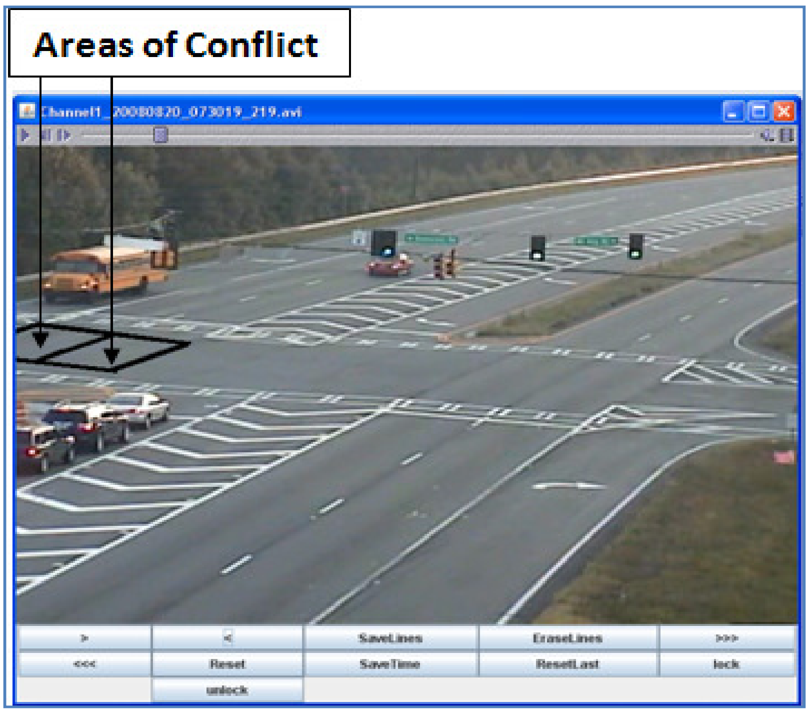


Figure 5 Screenshot of software setup for Post Encroachment Time data extraction

DATA ACCURACY

The 900 ft approach zone is covered by two cameras. Naturally the viewing angles are quite flat (in the order of 5 degrees). As the distance from the camera increases, the detection lines get closer due to the perspective view. Consequently the error in recognizing the correct frame (as to when the vehicle touches the detection line) increases. The magnitude of granularity also depends on the distance between the two detection lines for which the speed is being calculated. In the current study, the distance between consecutive detection lines is 40ft. The difference in the calculated speed and the actual speed due to an incorrect frame recognition error changes with the actual speed.

If the user makes an error in recording the correct frame, the formula for calculating the recorded speed (inclusive of errors) is as follows:

$$V_{n+k} = f*d*v*1.4667/(f*d + k* v*1.4667) \quad (1)$$

$V_{n-k} = f*d*v*1.4667/(f*d - k* v*1.4667)$ (2)

where:

f: frames per second in the video
d: inter-detector spacing in feet
v: actual speed of vehicle in mph
k: error in the number of frames recorded
n: correct number of frames in which the vehicle travels d distance
V_{n+k}: Recorded speed when k more frames recorded
V_{n-k}: Recorded speed when k less frames recorded

The differences in the actual and recorded speeds corresponding to different vehicle speeds at 40 ft inter-detector spacing, using a video with a frame rate of 30 frames per second is shown in Figure 6. The number beside each curve represents the error in recognizing the correct frame.

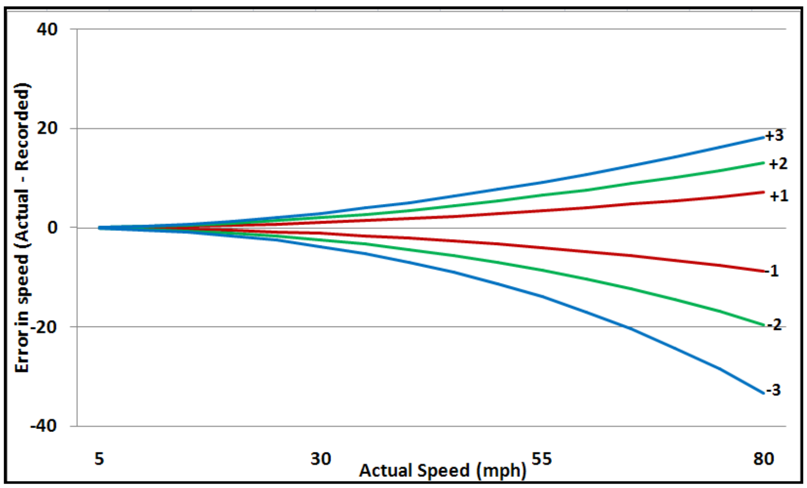


Figure 6 Error in speed corresponding to error in frame recognition

VALIDATION

To verify the accuracy of the data collection methodology and to obtain the optimal smoothing algorithm, geographic positioning system (GPS) probe vehicle was used. The comparison is performed between the data from GPS probe vehicle runs on the study site and the speeds generated using the software. The GPS equipment used had a specified accuracy of 32.8 ft (10m) in distance, 0.328 ft/s (0.1 m/s) in velocity and 1 microsecond in time (HI-401BT User Manual). It provides second-by-second location (latitude and longitude) data of the probe vehicle for several validation runs. A time-space diagram and a velocity profile of the vehicle is generated with this data. The same vehicle is identified in the video and processed in the software to extract its distance and speed profiles. The profiles from the two methodologies are compared to validate the accuracy of the data collection methodology being used in the study.

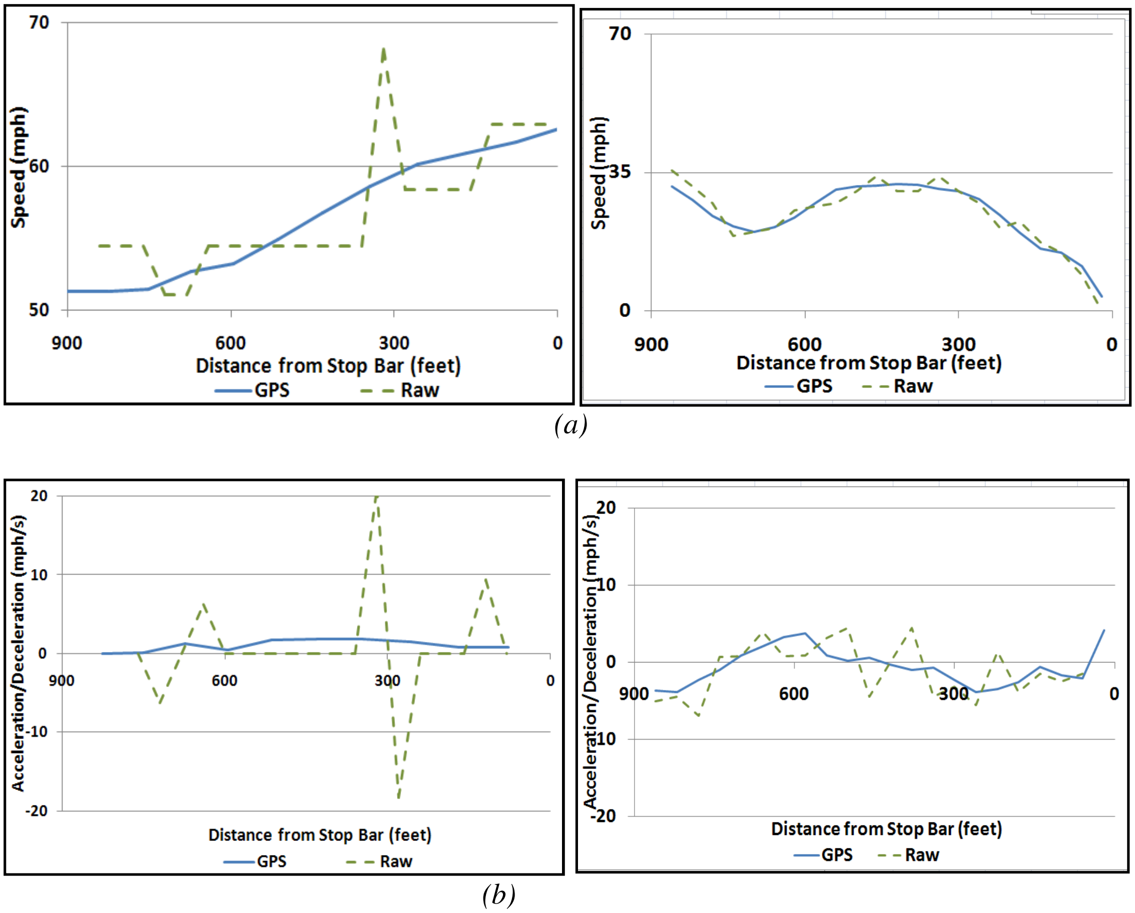


Figure 7 Example graphs showing (a) vehicle speed and (b) acceleration/deceleration profiles

The process of generating speed from video at a frame rate of 30 frames per second gave discrete speed readings which caused some noise in the data. As seen in Figure 7 some irregularities exist in the speed plot of the raw data. These irregularities can be attributed mostly to the data collection methodology, where discrete speed values are determined based on the number of frames required for a vehicle to travel the fixed distance between two detector lines (spaced every 40 ft in this study). Some irregularities are also a result of inherent error in identifying the frame in which a vehicle crosses a detector line.

Figure 6 and Figure 7 show that as the speed of the vehicle increases, the error and the noise in the collected data increase. In other words, this methodology would produce less error and/or noise in collected speed data (and the corresponding acceleration-deceleration profile) if the average speed of the vehicles is lower. Hence, this methodology gives more accurate results for such studies on arterial and other low-speed roads.

As the distance from the camera increases, the potential for this type of error increases due to the perspective view. Hence, low pass filters were developed to smooth the noise in the data. The smoothing algorithm is chosen such that it removes the nominal irregularities in the raw data due to discretization of the speed values, but does not smooth out the higher values of accelerations or decelerations of the vehicles. To obtain the algorithm that satisfies this requirement, a heuristic approach has been adopted. Various smoothing algorithms have been applied on the speed and acceleration data obtained. The simplest algorithm consists of an un-weighted moving average, replacing each point in the data with the average of 'm' adjacent points where m is a positive integer called the smooth width. For example, for a 3-point smoothing,

$$S_j = (Y_{j-1} + Y_j + Y_{j+1})/3 \tag{3}$$

where:
S_j : j^{th} point of the smoothed data
Y_{j-1}: $j-1^{th}$ data point before smoothing
Y_j: j^{th} data point before smoothing
Y_{j+1}: $j+1^{th}$ data point before smoothing

Based on comparison with the GPS "ground truth" data, a (3+5+7) smoothing algorithm was found to be optimum. This smoothing is defined by:

$$S_4\,(3+5+7) = (S_4(3\text{-point moving average})+S_4(5\text{-point moving average})+S_4(7\text{-point moving average}))/3 \tag{4}$$

$$= (15Y_1+36Y_2+71(Y_3+Y_4+Y_5)+36\,Y_6+15Y_7)/315 \tag{5}$$

where:
S_j : smoothed j^{th} point
Y_{j-3}: $j-3^{th}$ data point before smoothing
Y_{j-2}: $j-2^{th}$ data point before smoothing
Y_{j-1}: $j-1^{th}$ data point before smoothing
Y_j: j^{th} data point before smoothing
Y_{j+1}: $j+1^{th}$ data point before smoothing
Y_{j+2}: $j+2^{th}$ data point before smoothing
Y_{j+3}: $j+3^{th}$ data point before smoothing

Table 1 Mean Squared Error values of smoothing algorithms tested

Source	Speed MSE				Acceleration/Deceleration MSE			
	Run1	Run2	Run3	Run4	Run1	Run2	Run3	Run4
Raw Data	4.2064	223.70	6.1851	7.7086	34.628	221.15	54.943	59.573
3-point	2.3092	2.7471	2.0545	2.3736	3.2787	14.240	4.3531	6.8987
5-point	2.1231	1.2894	1.4883	0.7152	1.1828	4.1645	2.1921	2.3559
3+5 point	2.1249	1.4812	1.496	1.0661	0.9090	4.0613	1.0823	2.8395
7-point	2.0728	1.5019	1.3690	0.4884	1.1237	3.5335	1.2424	2.1304
3+5+7 point	2.0293	1.3009	1.115	0.5345	0.8272	1.6524	0.5876	1.8850
1+3+5+7 point	2.1102	1.7117	1.3819	1.1662	1.9950	3.4722	3.5620	5.7996

Table 1 shows the mean square error of various smoothing algorithms tested assuming GPS data as the ground truth.

Figure 8 shows the effect of the optimum smoothing algorithm (3+5+7) on speed data and comparison with the corresponding GPS data on several raw speed runs. Similarly Figure 9 shows the effect of the smoothing on acceleration-deceleration profiles and comparison with the corresponding GPS data.

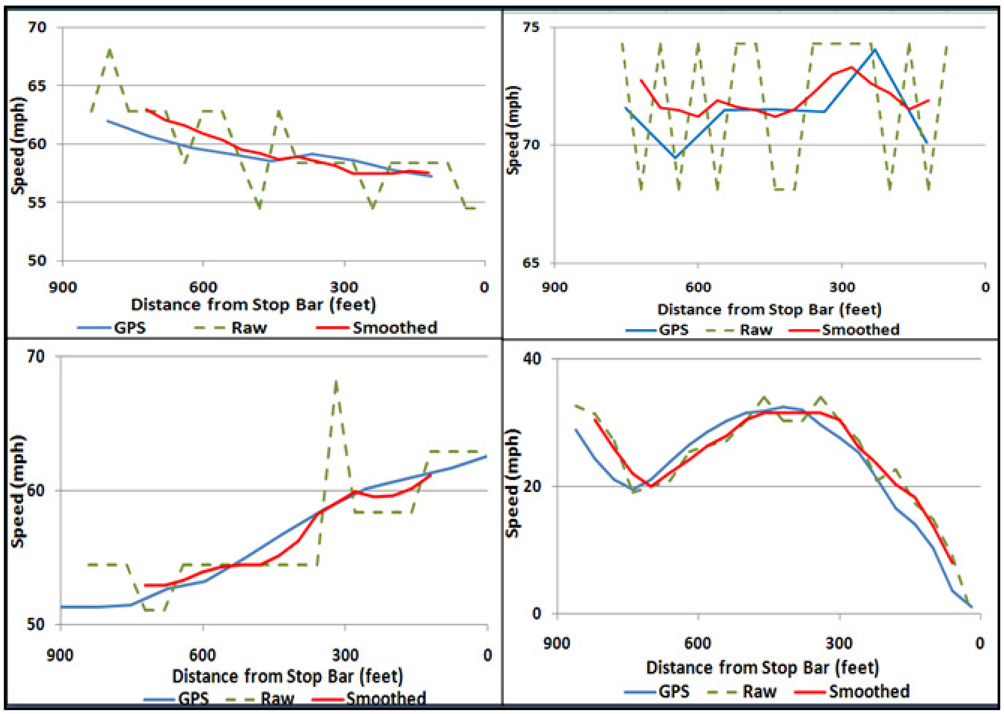


Figure 8 Effect of “3+5+7” weighted average smoothing algorithm on the raw speed profiles

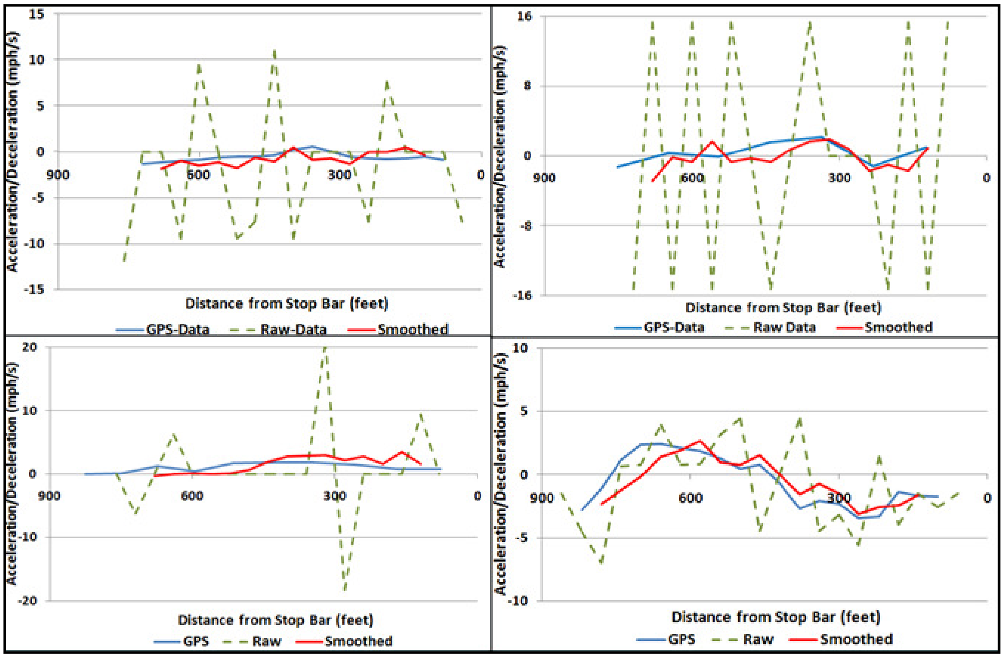


Figure 9 Effect of “3+5+7” weighted average smoothing algorithm on the raw acceleration/deceleration profiles

In both these figures, it can be seen that the speed and acceleration-deceleration profiles after applying the (3+5+7) smoothing algorithm approximate the profiles from GPS data. It is noteworthy that the algorithm performs well even for lower speed vehicles, indicating that the algorithm does not over-smooth the data which might otherwise cause the loss of critical acceleration and deceleration values.

EXAMPLE APPLICATION

The methodology discussed in this paper was applied to the study intersection and the surrogate data results for the southbound approach are presented here. The surrogate measures evaluated were:

a) the acceleration/deceleration values of through vehicles,
b) the Post Encroachment Time (PET), and
c) the speed with which the through vehicles enter the intersection.

The videos collected at the study intersection were processed to obtain the speed and acceleration-deceleration profiles of both northbound and southbound through vehicles using the custom software described earlier.

For each mainline approach to the intersection a minimum of one week of video was recorded to ensure representation of each day of the week. To minimize chances of data corruption and data loss, video was stored as a series of 10 minute clips. Approximately 16 hours of video was collected each day during the daylight (and twilight) hours, resulting in ninety-six (96) 10-minute videos. As data reduction is highly resource intensive (approximately four hours of processing for each ten minute sample), a single 10 minute sample is extracted from each hour as representing that hour. The ten minute period selected for each consecutive hour is shifted by ten minutes in an attempt to avoid a bias over the day (i.e. selected segments are 70 minutes apart).

To obtain a baseline dataset of the behavior of vehicles approaching an intersection, which are not influenced by potential opposing left turns or a standing queue, the time position data collected from the above sampling plan for a sample day is extracted for all the through vehicles approaching the intersection that meet the following conditions:

(1) vehicle did not have any opposing left-turning vehicles at the intersection (during the entire period of traversal of the vehicle through the observed section)
(2) vehicle was uninterrupted, i.e., did not need to stop for the signal or a queue.

Analysis of these vehicles allows for a determination of driver behavior in the absence of left turning vehicles or a standing queue. For the remaining days of the analysis period, data is extracted (according to the above sampling plan) for only those through vehicles satisfying the following conditions:

(1) There is an opposing left-turning vehicle waiting to cross the intersection or that crosses the intersection while the through vehicle is within the approach area under study.
(2) The opposing left and through vehicle are both facing a green signal indication, thus the opposing left should proceed only if it has a sufficient gap.
(3) There is no standing queue of through vehicles at the intersection (such as the tail of a queue formed during the red phase) which would affect the behavior of the approaching through vehicle.

These conditions were established to capture the behavior of vehicles directly related to the objective of this effort, i.e. measuring the effect of the installed treatments on the vehicle behavior during potential conflicting intersection movements. By extracting data exclusively for these vehicles during the remaining 10 minute clips the data extraction time per 10 minute clip is reduced, allowing for more vehicles of interest to be sampled.

To evaluate the effectiveness of this data collection methodology we evaluate the ability of the data to produce data sets for several surrogate safety measures considered to be potentially useful for evaluating intersection safety. The first surrogate measure considered is the acceleration/deceleration profiles of through vehicles and two complementary analyzes of the through vehicle acceleration/deceleration data. The first acceleration/deceleration analysis uses data from the entire vehicle trajectory as the vehicles approach the intersection. However, a conflict may be characterized by large decelerations due to the application of brakes to avoid a collision. Therefore, we also consider the maximum deceleration rate of the through vehicles. Figure 10 (a) shows the CDF of the observed acceleration values from the first analysis (4527 observations). Figure 10 (b) shows the distribution of maximum decelerations experienced by through vehicles (300 observations). Both plots illustrate the ability of the methodology to characterize large numbers of vehicles not only in terms of speed but also of deceleration distributions. In examining Figure 10, it is interesting to note that the deceleration values fall within the comfortable deceleration value of 7.63 mph/s (11.2 ft/s/s) typically utilized in intersection signal design (AASHTO (2004)).

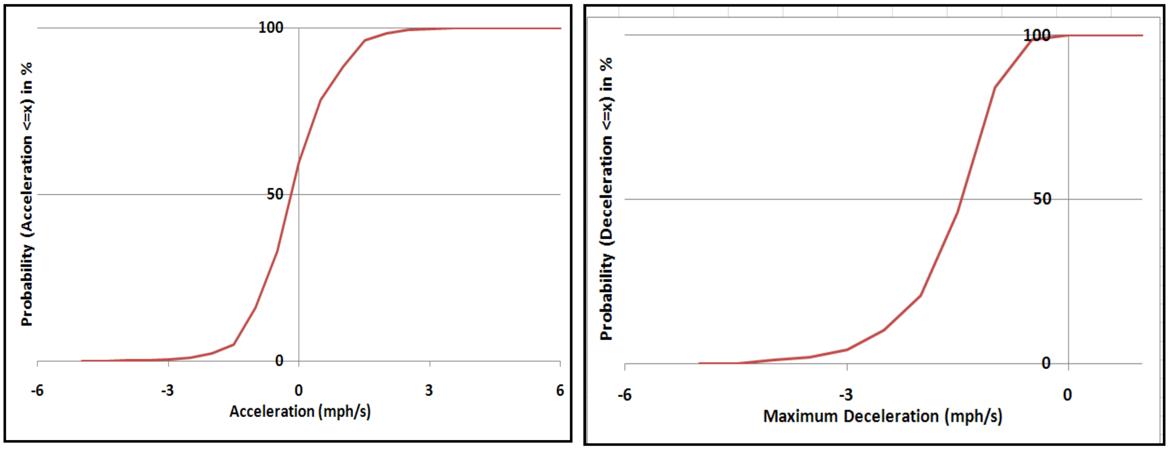


Figure 10 (a) CDF of the acceleration/deceleration profiles - 4527 observations (b) CDF of the maximum decelerations, southbound approach – 300 observations

The next surrogate measure considered is PET that is defined as the time lapse between the end of encroachment of the turning vehicle and the time that the through vehicle arrives at the potential point of collision. Any increase in the level of alertness in the drivers resulting from the treatments might be expected to be reflected in an increase in the PET. Figure 11 shows the CDF of the PET values observed between the left turn and opposing through vehicles (503 observations). In this case, the Figure illustrates the ability of the technique to evaluate surrogate measures derived from the motion of multiple vehicles.

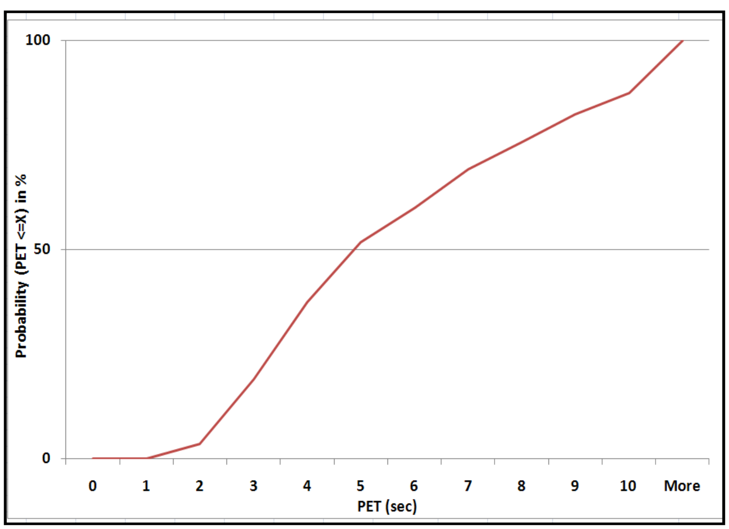


Figure 11 CDF of the PET values, southbound approach - 503 observations

The last surrogate measure considered was the intersection approach speed. Figure 12 shows the CDF of the southbound approach speeds as they enter the intersection (503 observations). The speeds with which the through vehicles enter the intersection range between as low as 50 mph to as high as 85 mph.

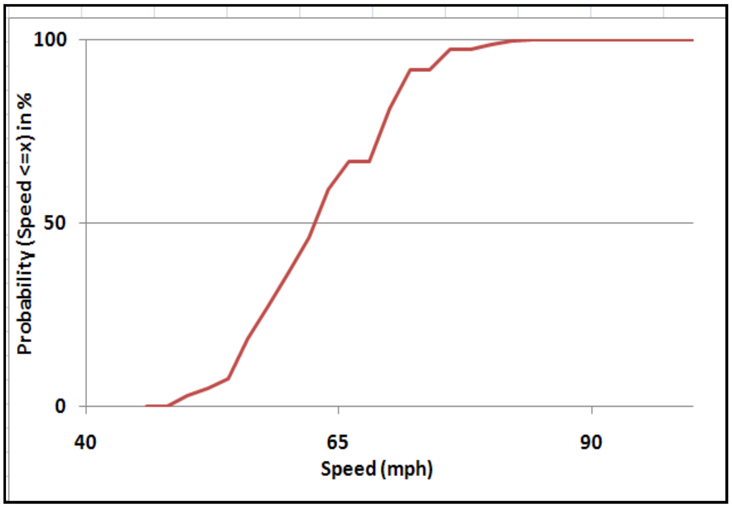


Figure 12 Speed of through vehicles entering intersection proper, southbound approach -503 observations

The results and the discussion presented above demonstrate that the developed methodology is capable of capturing the conflict between a left-turn vehicle and an opposing through vehicle in the form of surrogate measures such as acceleration/deceleration profiles of the through vehicles, PET and the speed with which through vehicles enter the intersection. This methodology can also be applied to capture the conflict after the application of the safety treatment. The surrogate data obtained before and after the application of the treatment can be compared to evaluate the effectiveness of the treatment.

CONCLUSIONS

The purpose of this research is to develop a methodology for surrogate safety data collection. The methodology presented successfully extracts speed, acceleration/deceleration profiles of individual vehicles from video data and PET, which can potentially be used as surrogate measures to evaluate the effectiveness of a safety treatment by comparing the before and after surrogate data. A semi-automatic method using custom software was developed for extracting the surrogate safety data from videos as the methodology requires collecting speed data at fixed intervals along a longer stretch of approach road. This semi-automatic approach allows for the use of lower camera angles with larger perspective views thereby limiting equipment needs, a limitation of most of the automatic video detection equipment based approaches. The methodology involves plotting the speed profiles and acceleration-deceleration profiles of vehicles that have not been studied to date as safety surrogates in detail before owing to the difficulty in measurement. For example, acceleration-deceleration values above a threshold could indicate possible maneuvers to avoid potential collisions which demonstrate their usage as potential measures of surrogate safety. This research also shows that the presented methodology would produce less error and/or noise in collected speed data (and the corresponding acceleration-deceleration profile) if the average speed of the vehicles is lower. Hence, this methodology gives more accurate results for such studies on arterial and other low-speed roads. Future research will involve application of this approach to evaluate the effectiveness of safety treatments by collecting before and after treatment surrogate data and may involve additional enhancements such as automated video processing to reduce the manual labor involved in the current methodology.

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