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TRCLC 15-7

January 15, 2017

App-based Crowd Sourcing of Bicycle and Pedestrian Conflict Data

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FINAL REPORT

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Transportation Research Center
for Livable Communities

Western Michigan University | University of Texas at Arlington | Utah State University | Wayne State University | Tennessee State University

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16. Abstract

Most agencies and decision-makers rely on crash and crash severity (property damage only, injury or fatality) data to assess transportation safety; however, in the context of public health where perceptions of safety may influence the willingness to adopt active transportation modes (e.g. bicycling and walking), pedestrian-vehicle and other similar conflicts may represent a better performance measure for safety assessment. For transportation safety, a clear conflict occurs when two parties' paths cross and one of the parties must undertake an evasive maneuver (e.g. change direction or stop) to avoid a crash. Other less severe conflicts where paths cross but no evasive maneuver occurs may also impact public perceptions of safety. Most existing literature on conflicts focuses on vehicle conflicts and intersections. While some research has investigated bicycle and pedestrian conflicts, most of this has focused on the intersection environment. In this project, we propose field testing a crowd-sourced data app to better understand the continuum of conflicts (bicycle/pedestrian, bicycle/vehicle, and pedestrian/vehicle) experienced by pedestrians and cyclists; the study also tests the effectiveness of the app and its associated crowd-sourced data collection. This study assesses the data quality of the crowd sourced data and compares it to more traditional data sources while performing hot spot analysis. If widely adopted, the app will enable communities to create their own data collection efforts to identify dangerous sites within their neighborhoods. Agencies will have a valuable data source at low-cost to help inform their decision making related to bicycle and pedestrian education, enforcement, infrastructure, programs and policies.

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Executive Summary

Most agencies and decision-makers rely on crash and crash severity (property damage only, injury or fatality) data to assess transportation safety. But, as are rare and random events; often times, the rare and random nature of collisions/crashes require researchers to gather several years of data to produce statistically significant estimates that discard the stochastic variations. Moreover, collision or crash data may be biased and underrepresent actual issues of safety that exist. However, in the context of public health where perceptions of safety may influence the willingness to adopt active transportation modes (e.g. bicycling and walking), pedestrian-vehicle and other similar conflicts may represent a better performance measure for safety assessment. According to the definition of traffic conflict from Amundson and Hayden (1977), a conflict is "an observable situation in which two or more road users approach each other in space and time for such an extent that there is a risk of collision if their movements remain unchanged." More importantly, because of the frequency of occurrence, conflict data can be coupled with crash data for better understanding the conflict patterns and the failure mechanism that leads to a collision, which can assist municipalities, transportation agencies and decision makers in making strategic responses to potential concerns. At the same time, conflict measures can act as a sketch level planning performance measure (surrogate safety measure) to understand potential safety issues related to transportation facilities.

Traffic conflicts have received more attention since their first introduction. The U.S. Department of Transportation Conflict Technique (USDOTCT) from the Federal Highway Admiration (FHWA) categorizes various elements that induce conflicts; identifies the severity levels of each element and finds the overall grade of the severity of the conflict. Like the USDOTCT, the Swedish Traffic Conflicts Technique (STCT), and the Institute of Highways and Transportation Conflicts Technique (IHTCT) were developed for vehicle to vehicle conflict analysis. However, some vehicle-vehicle conflict based methods also may be adopted to consider vehicle-pedestrian conflict analysis; these include, modelling the interaction between left-turning vehicles and pedestrians at signalized intersections, assessing the efficiency of safety regulations for vulnerable road users at intersections, and qualitative categorization of conflict types and severity. Also, a modified version of the IHTCT method was used to develop a vehicle-pedestrian conflict analysis method. However, few studies have considered conflict analysis as a performance measure of safety for active transportation modes. More recently, a Transportation Research Center for Livable Communities (TRCLC) study (Casey et al., 2016) developed conflict analysis performance measures as a surrogate safety measure for both pedestrians and bicyclists. This study identified three key conflict factors (i.e., separation distance, vehicle or bicycle speed, and time to take any evasive action) that influence the conflict seriousness. Unfortunately, the availability of conflict data remains very sparse as most of the time near miss incidents never get reported; therefore, the connection between the conflict that has occurred and the potential crash occurrence remains unclear.

This study seeks to provide an innovative approach for collecting bicycle and pedestrian conflict data. Specifically, the study proposes to develop a smart phone app to capture data using crowd-sourcing for the continuum of conflicts experienced by pedestrians and cyclists within different types of transportation infrastructure. In the pursuit of this goal, the study will:

a. Identify user needs/requirements and develop app training support
b. Create a smartphone app for collecting bicycle and pedestrian conflict data
c. Create a data subscription service for agencies and community organizations to access the gathered data
d. Perform severity analysis of different types of conflicts from the crowd-sourced data and identify hot spots from the crowd sourced conflict data and traditional crash data.

A crowd-sourced data collection effort may lack some of the data quality of a more formalized approach; however, the data can be gathered in a cost-effective manner while also reducing the time needed to collect the data. Crowdsourcing has also been found to be useful in transportation because it voluntarily brings together a large group of people into the same platform around a common issue. This data can be used by agencies and community organizations to identify and prioritize strategies for responding to potential public health concerns for bicyclists and pedestrians.

The entire crowd-source data collection process for conflict analysis included three broad phases. At the beginning of the project, the research team performed an extensive literature review to identify the key features associated with conflict analysis for better understanding the continuum of conflicts between transportation modes. At this stage, they also identified key stakeholders related to bicycles and pedestrians and developed a contact list for future involvement in the app snowballing process. Utilizing stakeholders during the various parts of a study can increase the validity of the study by verifying specific needs and present an opportunity to gain additional knowledge from an outside source. Most of the stakeholders such as Tarrant County Public Health, Dallas County Public Health, City Public Health, NCTCOG, National SAFE KIDS Campaign, Kalamazoo Bicycle Club, City of Dallas, and City of Denton associated with this study can be characterized into three general groups;

- Those concerned with bicycle and pedestrian safety,
- Those concerned with public/environmental health, and
- Those concerned with city/regional planning and management.

In the next step, the research team developed the functional requirements of the app along with user interface requirements and end user requirements. This helped the research team to gather potential key features for the app and design the app prototype. The research team then tested the prototype and obtained feedback from the stakeholders.

During the feedback process, the research team received valuable information related to both the design and functional requirements. Based on the feedback, the team developed a beta version for the app and the corresponding database. Later, the team tested the beta version of the app in a junior-level Transportation Engineering class (Spring 2016) at the University of Texas at Arlington (UTA). During the beta test, student teams observed the commute periods for four different school locations to record all conflicts. The students also provided feedback on app performance and functionality based on their experience at the end of the data collection process. After correcting the remaining concerns, the team made the final version of the app available in Google Play Store. Later, the research team contacted the stakeholders who agreed to take part in the snowballing process during previous focus group meetings. The team sent out an app snowballing invitation and asked the stakeholders and the Fall 2016 students in the same junior-level Transportation Engineering class to take part in the app field test and data collection. This time, the students gathered information from almost 25 different elementary school locations. After the end of one month of data collection, the participants provided feedback on the user-friendliness of the app and its different features.

In response to the comments received from the field test participants, the team finalized the app with only two user groups. The regular or standard user group includes all app users who will be recording conflict scenarios. These users will receive a reminder once a day for recording a conflict, and they will also receive prompt notification of any conflict recorded their current zip code. This helps the users keep track of hot spot locations around their activity paths. The second user group represents those that will work with the data while at the same time they can also use the app as a regular user. These end users will use the data sharing option of the app to share the required database for any conflict analysis. The database

can be shared as a *.CSV file or as a *.KML file, which can be opened in an Excel file or in a Google map file respectively. The admins also have the option to add other users as an admin.

The initial field test of the app shows promise with support from many users in continuing to use the app and the app's effectiveness in mapping conflicts to previously recorded fatalities. Most of the field test users find the app easy to use and the survey questions easy to complete. This study presents some significant opportunities for further research and development. Now that the concept has been proven, modifying the app to function on different platforms represents the most critical next step in the product development process. As such, the app will require further testing on a range of mobile devices (i.e., various models of Android, iPhone, Windows Phone). Future enhancements to the app may include giving access to various advocacy groups or running or biking groups to use their identity inside the app. This will help those groups customize the app according to their needs while also providing the essential data for end users. One possible enhancement may be the ability for an agency or advocacy group to respond to feedback emails from users in their jurisdiction or group. A detailed strategy on trying to snowball the app adoption among both end users and app users requires further development, and likely represents a research project exploring the role of social media/networks in the adoption of a crowd-source data collection instrument. As this project included the app as part of a class project, its use as a learning tool may be explored in more detail. Specifically, the future educational research should seek to assess the impact of the using the app on increasing the performance of students on learning outcomes related to bicycle and pedestrian safety and design.

1. Introduction

1.1. Conflict analysis as a surrogate safety measure

Collisions are rare and random events. Often times, researchers have to gather several years of data to produce statistically significant estimates to discard the variations due to the stochastic nature of collisions. Moreover, collision or crash data may be biased and underrepresent actual issues of safety that exist. On the other hand, a conflict is "an observational situation in which a vehicle [can also be a pedestrian or a bicyclist] and pedestrian [can also be a bicyclist or a vehicle] approach or encroach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged" (1, 55). As such, conflicts (or near miss situations) often pose potential safety concerns for both pedestrians and bicyclists. But because of the frequency of occurrence, conflict data can be coupled with crash data for better understanding the conflict patterns and the failure mechanism that leads to a collision, which can assist municipalities, transportation agencies and decision makers in making strategic decisions (2). Moreover, conflict measures can act as a sketch level planning performance measure (surrogate safety measure) to understand potential safety issues related to transportation facilities.

1.2. Key Research Gaps

While, collision or crash data plays a key role in modeling the pedestrian or bicycle injury risk as a function of transportation characteristics, pedestrian safety analysis using non-collision data mostly relies on traffic conflict analysis (3-11). Initially, only quantitative methods assessed the road user response to conflicts, but gradually more quantitative techniques have emerged in conflict analysis (12-20). The U.S Department of Transportation Conflict Technique (USDOTCT) from the Federal Highway Admiration (FHWA) categorizes various elements that induce conflicts; identifies the severity levels of each element and finds the overall grade of the severity of the conflict (15). Like the USDOTCT, the Swedish Traffic Conflicts Technique (STCT) (13), and the Institute of Highways and Transportation Conflicts Technique (IHTCT) (14) were developed for vehicle to vehicle conflict analysis. However, some vehicle-vehicle conflict based methods were also used for vehicle-pedestrian conflict analysis; these include, modelling interaction between left-turning vehicles and pedestrians at signalized intersections (21), assessing the efficiency of safety regulations for vulnerable road users at intersections (22), and qualitative categorization of conflict types and severity (23). Also, a modified version of the IHTCT method was used to develop a vehicle-pedestrian conflict analysis method (24). More recently, the Transportation Research Center for Livable Communities (TRCLC) study conducted by Casey et al. (25) developed conflict analysis performance measures as a surrogate safety measure for both pedestrians and bicyclists. This study identified three key conflict factors that influence the seriousness of the conflict. These three factors include: a) the separation distance, b) the speed of the vehicle or bicyclist, and c) the time to take any evasive action (*24*). But, the availability of conflict data remains very sparse as most of the time near miss incidents never get reported; therefore, the connection between the conflict that has occurred and the potential crash occurrence still requires proper analysis.

1.3. Problem Statement

This study seeks to provide an innovative approach for collecting bicycle and pedestrian conflict data. Specifically, the study proposes to develop a smart phone app to capture data using crowd-sourcing for the continuum of conflicts experienced by pedestrians and cyclists within different types of transportation infrastructure. A crowd-sourced data collection effort may lack some of the data quality of a more formalized approach; however, the data can be gathered in a cost-effective manner while also reducing the time needed to collect the data. Crowdsourcing has also been found to be useful in transportation because it voluntarily brings together a large group of people into the same platform around a common

issue (26). This data can be used by agencies and community organizations to identify and prioritize strategies for responding to potential public health concerns for bicyclists and pedestrians.

1.4. Goals and objectives

This research seeks to determine the effectiveness of using an app to crowdsource the gathering of bicycle and pedestrian conflict data. In the pursuit of this goal, the study will:

a. Identify user needs/requirements and develop app training support
b. Create a smartphone app for collecting bicycle and pedestrian conflict data
c. Create the data subscription service for agencies and community organizations to access the gathered data
d. Perform severity analysis of different types of conflicts from the crowd-sourced data and identify hot spots by comparing both the crowd sourced conflict data and traditional crash data collected from crash reports.

1.5. Methodology

The entire crowd-source data collection process for conflict analysis was divided into three broad categories. At the beginning of the project, the research team performed an extensive literature review to identify the key features associated with conflict analysis for better understanding the continuum of conflicts between transportation modes. At this stage, they also identified key stakeholders related to bicycles and pedestrians and developed a contact list for future involvement in the app snowballing process. In the next step, the research team developed the functional requirements of the app along with user interface requirements and end user requirements. This helped the research team to gather potential key features for the app and design the prototype of the app. The research team then tested the prototype and obtained feedback from the stakeholders selected to represent different agencies and advocacy groups. During the feedback process, the research team received valuable information related to both the design and functional requirements. Based on the feedback, a team developed a beta version for the app and the corresponding database. Later, the team tested the beta version of the app in a junior-level Transportation Engineering class (Spring 2016) at the University of Texas at Arlington (UTA). During the beta test, student teams observed the commute periods for four different school locations to observe all conflicts. The students also provided feedback on app performance and functionality based on their experience at the end of the data collection process. After correcting any remaining concerns, the team made the final version of the app available in Google Play Store. Later, the research team contacted the stakeholders who agreed to take part in the snowballing process during previous focus group meetings. The team sent out the invitation of the app snowballing and asked the stakeholders and the Fall 2016 students in the same junior-level Transportation Engineering class () to take part in data collection. This time, the students gathered information from almost 25 different elementary school locations. After the end of one month of data collection, the participants were asked to give feedback on the user-friendliness of the app and different features. The research group includes a detailed analysis of this feedback along with the conflict records to evaluate the app effectiveness. Figure 1.1 summarizes the project phases.

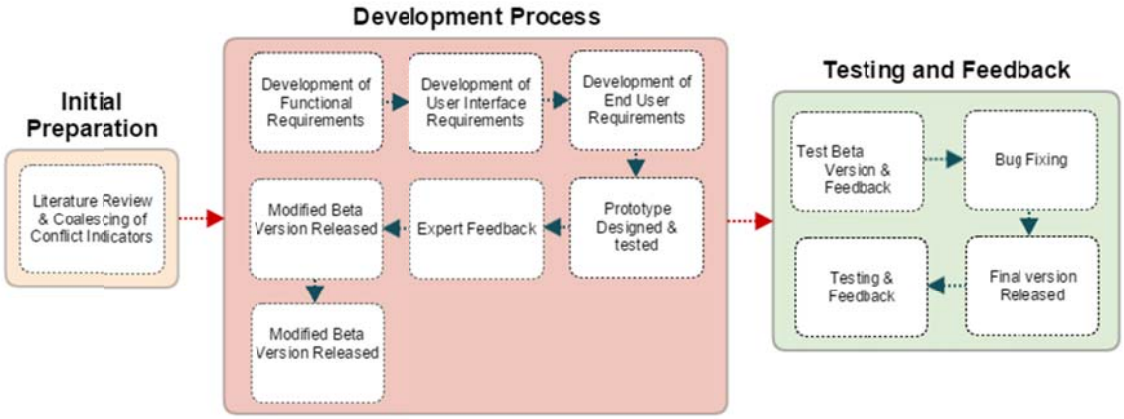


Figure 1 Flow chart of the crowd-sourced data collection process

1.6. Limitations

The new smart phone based data collection app not only will help collect more conflict data through crowd sourcing but it will also facilitate collection of other factors associated with conflicts and their severity levels. The researchers expect that planners and decision makers can carefully analyze different conflict scenarios with their severity level and compare the collected conflict data with crash data in order to identify the actual reason for those crashes. However, the research team also recognizes a few limitations associated with the proposed solution.

Firstly, although the crowd-sourcing data collection seems to have a major benefit and a number of research studies have proven that people are becoming good at comparing situation-specific risks (27-30), relying on human judgement creates inter- and intra-observer variability for the repeatability and consistency of results (31-33). Different people will have a different perspective during their experience and when considering vehicle speed, distance and time left for taking evasive action; the answer may fall under a vast range of values.

Secondly, the crowd-sourced data will also have a reasonable bias associated with the exact location. As the app uses a map based interface in locating the exact location of the incident and the users are asked to identify that, it may create erroneous records. The error associated with this type of scenario with a certain distance limit can change the infrastructure element from intersection to segment. Identifying how much distance level accuracy is needed for this type of analysis would require a more elaborate analysis of the crowd-sourced data accuracy from a location marker.

Lastly, crowd-sourcing data collection processes have long suffered from the lack of participants (34, 35) and this seems reasonable here in this study as well. The use of snowballing for the app beyond the initial stakeholders performed poorly, which resulted in the enlistments of only one end user taking part in the final testing of the app. Data collected by advocacy groups and experts would have enhanced the reliability of the research study and hence future strategies and recommendations appear important for better crowdsourcing of the app.

1.7. Report Formation

The rest of the report consists of five different sections. Section 2 reviews the literature associated with collision and conflict analysis and identifies the key stakeholders, the problems associated with present safety performance measures and issues with a crowd-sourcing data collection process. Section 3 of the report elaborately lays out different functional, user and end user requirements of the app. The next

section lays out the development process of the app. Section 5 discusses the experimental design of the app testing. Section 6 discusses the results of the testing and the feedback from the app users and then section 7 discusses the conclusions and future recommendations.

2. Literature Review

A current Federal statute, United States Code, Title 23, Chapter 2, Section 217 (CFR, 2001), mandates that "bicycle transportation facilities and pedestrian walkways shall be considered, where appropriate, in conjunction with all new construction and reconstruction of transportation facilities, except where bicycle and pedestrian use are not permitted." Cities and communities around the USA have seen a huge rise in active commuting. Some cities such as Lexington, Kentucky, and Portland, Oregon, have seen approximately a 300% growth in bicycle commuting over the last decade where San Francisco, California, New Orleans, Louisiana, and Anchorage, Alaska, have seen more than a 100% increase (37). This increase in active transportation modes not only enhances public health by decreasing obesity, but it also improves the environment by moving away from the old paradigm of vehicular mobility and access, which reduces fossil fuel usage and air pollution.

2.1. Severity of Crashes

While public health researchers argue about the societal health benefits of active modes (38), the increased level of exposure of pedestrians and bicyclist to vehicular movement creates safety issues. According to the World Health Organization (WHO) (2013), more than 270,000 pedestrians die worldwide each year and account for 22% of the total 1.24 million deaths from road traffic crashes (39). In the United States, 4,743 pedestrians were killed and nearly 76,000 were wounded in traffic accidents in 2012 (40). During the same time period, a total of 726 pedal cyclists were killed and an additional 49,000 injured in motor vehicle traffic crashes. A significant percentage of bicycle fatalities include children from the age group 5-15 (41). According to a report from the Centers for Disease Control (CDC) in 2005, traffic safety is the 2nd most common barrier for children walking to school (42). Evidently, these crashes have deterred pedestrians and bicyclists from using an active mode of transportation more frequently, and researchers have been trying to solve the problem for many years (43). A lot of researchers have done an extensive amount of study on pedestrian crashes (44-47) or bicycle crashes (48) or both pedestrian and bicycle crashes (49-51). But as collisions remain rare and random events, researchers have to gather several years of data to produce statistically significant estimates and discard the variations due to their stochastic nature. Moreover, the data quality of crashes remains low because of post-hoc description, witness accounts and site observations, which may underrepresent actual safety issues that exist. The ethical concern of the safety analyst to wait for an accident to happen to take any preventive measure also appears to be an issue. Clearly, only using crash analysis does not adequately portray the safety challenges that pedestrians and bicyclists face in their day to day movement.

2.2. Importance of Conflict Analysis

The perceived safety of walking or biking can only be truly observed through lived experience-participation, interaction and/or observation, which verifies that accidents often reflect the "tip of the iceberg" in terms of systematic risk (52). According to risk management and industrial accident prevention researchers, near misses appear much more predominant than their related incidents (53, 54). The series of events (e.g., braking, swerving and stopping) that lead to near-miss or traffic conflicts have similarities with the series of events (e.g., braking, swerving and crashing) preceding actual crashes (55). The only difference between a real crash and a near-miss as the term implies that in near-miss events the parties involved barely avoid the collisions where in a crash, they cannot.

Perkins and Harris (1967) propose the concept of conflict analysis as an alternative to collision data, which in many cases are scarce, unreliable, or unsatisfactory. They generally defined a traffic conflict as: ‘‘An interaction between two or more road users and an incident that induces the avoidance behavior of road users to avoid an imminent accident” (56). A formalized definition of a traffic conflict was later adopted as “an observable situation in which two or more road users approach each other in space and time for such an extent that there is a risk of collision if their movements remain unchanged” (57). Since then, safety researchers and practitioners increasingly use the traffic conflict techniques in assessing the safety of a road entity (intersection, road segment, etc.) (58, 59). As conflicts occur more frequently, a systematically observed conflict analysis can provide insight into the failure mechanism that leads to collisions (61) and thus help analyzing, diagnosing and solving safety problems (60).

2.3. Research Progress in Conflict Analysis

A more in depth knowledge on the severity of conflicts will help in evaluating transportation infrastructure safety conditions and predicting collisions. Various conflict indicators have been established to measure the severity of an interaction by quantifying the spatial and temporal proximity of two or more road users. The main advantage of conflict indicators is their ability to capture the severity of an interaction in an objective and quantitative way (61). Therefore, Hayden (1987) proposes the Swedish Traffic Conflict Technique as an expansion of Perkins and Harris’ concept, which systematically arranges the steps that must be taken in vehicle accidents (55). A comprehensive summary of the different indicators is provided in Brown (1994) and Tarko et al. (2009) (62, 63).

Hayward (1972) identifies the *Time-To-Collision (TTC)* as a major factor to describe the danger of a conflict situation (64). When attempting to extend this idea to rural intersections, Svensson and Hyden (2006) find that *vehicle speeds* also represent a dominant factor (64, 65). Various other researchers have studied the severity of conflict and identified that *time to collision*, *distance* and *speed of the approaching vehicle* may contribute to severity. More recently, a comprehensive study from Casey et al. (2016) has developed conflict analysis performance measures for both pedestrians and bicyclists for both intersections and segments (25). The research team considers two broad types of conflicts for both pedestrian and bicyclist interactions with the transportation infrastructure. A non-overtaking (or angled) conflict type occurs when parties (pedestrians, bicyclists, or vehicles) are not travelling in the same direction. Overtaking conflicts occur between parties that are travelling in the same direction. The three factors considered in this study to measure the severity of conflict include speed of the approaching/crossing vehicle, lateral/longitudinal distance of the vehicle and time to take action. In total, the study considers the following five types of conflicts:

- Pedestrian – Vehicle
- Bicyclist – Vehicle
- Pedestrian – Bicyclist
- Vehicle – Bicyclist (Overtaking)
- Bicyclist – Pedestrian (Overtaking)

This study adopts these key elements of conflict analysis in the development process of the app and uses the app to collect information on these variables.

2.4. Stakeholders associated with Conflict Analysis

Utilizing stakeholders during various parts of a study can increase the validity of the study by verifying specific needs or present an opportunity to gain additional knowledge from an outside source. After reviewing various pieces of literature, gathering a set of stakeholders requires putting together a diverse

group of individuals that have backgrounds associated with the key aspects related to the project (67). The stakeholders associated with this study can be characterized into three general groups;

- Those concerned with bicycle and pedestrian safety,
- Those concerned with public/environmental health, and
- Those concerned with city/regional planning and management.

In this case, more than 30% of the stakeholders have a relation with bike and pedestrian safety in some capacity. Many of these stakeholders are affiliated with North Central Texas Council of Governments (NCTCOG) or with the planning departments in numerous cities. Examples of some stakeholders associated with this project are:

Table 1 Examples of Stakeholders Associated with the Project

Category	Examples
Bike/Ped	NCTCOG, National SAFE KIDS Campaign, Kalamazoo Bicycle Club
Health	TCPH, DCPH, MDCH, City Public Health
Planning	City of Dallas, City of Denton, NCTCOG

The stakeholders who work or are associated with bicycle and pedestrian safety consist of metropolitan planning organizations (MPOs), advocacy groups and statewide bicycle-pedestrian coordinators. Tarrant County Public Health (TCPH), Dallas County Public Health (DCPH), and other community health organizations represent examples of stakeholders for public/environmental health group. Lastly, the stakeholders of the planning division include cities, consultants, and MPOs. A comprehensive list of the stakeholders are tracked in an Excel file from the beginning of the project (**Appendix A**), arranged by their particular affiliation or organization. The initial stakeholders were obtained to complete a survey in order to better understand their needs, wants and concerns. They were then used in order to develop a snowball effect where they were able to name additional individuals who may have an interest in participating in the study. The final list of all individuals named as stakeholders will be listed in **Appendix A** and includes all initial stakeholders and the stakeholders obtained through the snowball effect. The last phase of testing for the app's development includes this final group of stakeholders.

2.5. Conflict Analysis Data Collection

Despite the fact that several studies have demonstrated the feasibility of collecting conflict data using (i) field observers (56; 67-71), (ii) simulation models (72-77), and (iii) video-camera (78-81, 61), they all have pros and cons associated with them. For example, simulation models can not consider the unexpected behaviors of parties involved in a conflict and research on sophisticated video data collection and automated video data analysis process remain in the development level (61). Sending field observers to conduct conflict surveys may be the most practical solution as numerous research studies confirm that people seem relatively good at comparing situation-specific cycling risks (82-85). Knowles et al. (2009) also find in their research that self-reported conflict reports almost accurately matches with the event and provides an 'early warning' sign of possible injury behavior (86). While conflict analysis will provide better understanding of the crash occurrence and improve safety of active mode users, the lack of an extensive database hinders its further improvement. Crowdsourcing data from users will not only reduce the cost of collecting conflict data, but it also enhances a database by collecting various level of information, which otherwise remain unreported.

3. Crowdsourcing and its Legal Issues:

In this particular case, the new Android based app called *Safe Activity* utilizes crowdsourcing in order to generate mass data about potential safety issues from a pedestrian's or bicyclist's point of view. Although crowdsourcing represents a newer concept in transportation planning and research, it can be beneficial by limiting the cost related to data collection, creating a more efficient system of data retrieval, and minimizing the time to conduct data collection. However, because utilizing crowdsourcing as a form of data retrieval in transportation remains new, some limitations exist such as accuracy, unusable, and uncertain biased data collected based on the user's accuracy. Despite the potential disadvantages affiliated with crowdsourcing, with informed subjects and clear, concise statements, this method of data retrieval can vastly innovate transportation planning and safety analyses. If and when an app user faces a near miss or potential conflict while engaging in an outdoor activity, he or she may log into *Safe Activity* and follow the simple question and answer format in order to generate a severity index for his or her specific incident. Once this information has been submitted, it is stored in Amazon Cloud and formatted into files that can be used by municipalities and transportation planners for further research. The app not only uses crowdsourcing as a form of data retrieval, but it also allows the users to see conflicts that have been logged by other users, which in return crowdsources knowledge about the safety issues that are present near them.

When considering the collection of data through crowdsourcing and mobile applications, legal issues appear inevitable. One of the most prevalent issues related to any data collection project lies within the privacy and rights of its users. This problem can be faced at various points in the project and even after the project life has expired. During the development phase, the study conducted surveys and stakeholder interviews, which required collecting personal information from the human subjects to enhance the development and testing process. Due to the fact that this project utilized human subjects and was being federally funded, the UTA Institutional Review Board (IRB) provided review and approval of the research protocols prior to initiating the research. On January 27, 2016, the UTA IRB assigned an exemption to the project under Title 45CFR Part 46.101(b) (2) referenced from the federal guidelines for the protection of human subjects. Once the IRB completed its review and gave approval, all human subjects who wished to participate in the research study received an Informed Consent Document prior to their participation. This document includes phrasing that ensures the subjects' knowledge of voluntary participation, lack of penalty if participation is discontinued, lack of compensation for participation, right to decline participation, the research procedures, and a confidentiality clause.

Additional issues related to the application and crowdsourcing included the collection of personal information (email address), GPS monitoring within the mobile app, and storage of the data in the Amazon Cloud. As the mobile app only collects the email from the users, limited personal information is actually obtained within the app itself. GPS monitoring is also not available on this app in particular, and therefore, the movements of the users is not recorded or stored. The user must input their conflict location or drop a pin in order to record the data they wish to input, but this feature will only record the single location that he or she wishes to log. Users can also use a "My Location" feature which will display a map of logged conflicts near their current location; however, this location information will not be stored unless an additional pin is dropped or a conflict is recorded. By making the mobile's continuous GPS tracking unavailable in the app, the users' locations are kept private whether the app is running or not and only recorded when they choose to do so. These features limit what is being put into the storage cloud, and only allows information that the users have voluntarily submitted to be recorded while minimizing/eliminating and identifiable information (except the email ID) to be associated with the submitted information.

4. Design Requirements

At the beginning of the project, the research team identified various factors associated with conflict analysis and used them to prepare the prototype of the app. This prototype is then tested among carefully selected experts for feedback on the app's interface and functional requirements, and the end user requirements, which are explained in detail in the following sections.

4.1. Primary Investigation of Conflict Analysis and Identification of Indicators

This study considers the aforementioned categories of conflicts, their definitions and the variables that define the severity level. The recent research performed by Casey et al. (2016) focuses on developing a conflict analysis methodology as a surrogate safety measure. This TRCLC study surveys key policy-makers and experts on previously defined overtaking and non-overtaking conflict factors. As mentioned earlier, this study defines five different types of conflicts and severity evaluation factors; a detailed summary table of these can be found in the **Appendix B**. The aforementioned TRCLC report also develops a performance measure metric for different conflict scenarios and defines them for four different severity levels (25). This crowd-source data collection study considers those severity levels and assigns them for different combinations of conflict scenarios. **Appendix C** provides the severity of these scenario based conflict situations user convenience.

4.2. Stakeholders Recruitment Process

For the focus groups, the study group recruits two groups: "app users", and the "end users". App users include those who utilize non-motorized modes of transportation (pedestrian, runners, and bicyclists). Meanwhile, end users include those professionals representing local and regional government officials, bicycle-pedestrian coordinators, and nonprofit groups. The research group recruited "bikers, walkers, and cyclists" from contact information obtained through running, walking and bicycling organizations around the Dallas-Fort Worth (DFW) area. Additionally, NCTCOG, the MPO for the North Central Texas region, helped to recruit "end users" through their database of local government contacts and organizations using an email about the research and an invitation to the focus groups sessions.

4.3. Focus Groups Interview Protocol

The team conducted two sessions of focus group: 1) potential app users held on March 2, 2016; and 2) potential end users held on March 3, 2016. Each focus group lasted approximately 45-60 minutes with 5-10 participants in each session. Both focus groups were audio recorded and held at the NCTCOG office. Some interest, mainly from potential app users, in focus group participation could not be accommodated due to time and location constraints.

4.3.1 App user focus group

The purpose of the focus group with potential app users was to determine what information they were willing to enter and features that can be useful to improve safety. The research group prepared prototype app interfaces and showed them to the group during a presentation at the beginning of the interview (**Appendix D-1**); they also asked the participants questions about user friendliness, usefulness, and features that a user would find beneficial to encourage daily app use. After the discussion, each participant was given a questionnaire that asked "bikers, walkers, pedestrians" to provide a list of the kind of conflicts they encounter during a walk, ride and run; ideas for an easy way for them to log this information on an app on a daily basis; as well as other route information they would like to provide to local governments.

4.3.2. End user focus group

The purpose of the focus group with end users was to discuss with local government officials and transportation agencies the types of pedestrian and bicyclist conflict data needed to better improve safety through transportation infrastructure and services. The research team showed a series of images for the app's interface and the type of information that can be gathered via the app in a presentation at the beginning of the focus group (**Appendix D-2**). The focus group for end users discussed the type of data that can be collected from an app-based crowdsourcing tool to inform decisions regarding investments to increase biking, walking and running safety in their community. The questionnaires for end users asked for input on data needs, desires, and concerns that can help increase biking, walking and running safety in their community.

4.4. Feedback from stakeholders

The major feedback from the two different focus groups is:

- Participants at the focus group for app users suggested that near misses and crashes remain under-reported
- The app interface needs to be simplified; graphics and images should only be present if necessary
- One of the ways to provide incentives for app users to use the app daily is by encouraging forms of a community of app users that allow users to see and share information about conflict incidents and crashes
- A community of app users could be connected as a part of a larger social media platform
- Participants at the focus group for end users had concerns about the accuracy of self-reported incidents
- A participant (end users) inquired whether there was a way to record who was responsible for conflicts
- Data needs to be available even if end users do not have GIS program capacity.

4.5. App user's requirements

The functional and user interface requirements for this application derive from the input obtained from the two focus groups (app user and end user). Table 2 describes the desired features of the app, its functional requirements and the cloud service.

4.6. End User Requirements

4.6.1. Search and Download conflict information

The application provides an interface, which allows the user to search through the conflicts by zip code or distance in miles. An app user has the capability to search conflicts through three different filters including; 1) the users' own conflicts, 2) all conflicts recorded in an area by zip code, or 3) all conflicts recorded in an area by distance in miles. As an end user or admin, methods for downloading are also present once the search has been completed. As per capabilities, these users should be able to download the conflicts. The download option gives a way to share conflict information with end users. Conflicts can be downloaded using either a CSV or KML format. The CSV format facilitates sharing information in a text format with end users, and it works with applications like Microsoft Excel for viewing and analyzing the conflict data. A detailed data dictionary associated with the app is also available to download from the app (**Appendix E**). Applications like Google Earth and Google Maps can view the KML files.

4.6.2. Location search

The application should provide a user interface to easily search a particular location using map view. Users should be able to search a location by name or zip code.

4.6.3. Data subscriptions service

The application's user interface shows all conflicts by search filter in text format in the list view, which is sorted by time. This application should provide an interface that can access information in CSV [15] or KML [16] file formats, which can be downloaded and shared.

The assigned flow of the survey questions are shown in the flow chart shown in Figure 2.

Table 2 Desired Features of the app and their Functional requirements

	Desired Features	Interface Requirements	Functional Requirements
1	Sign In and User Identification	The user should have a sign in option where he/she can user his/her email ID and log in	Every conflict recorded should be associated with some unique identifier that represents the user who recorded the conflict
2	Map View	The application provides a full screen map view to the user. It also displays the street names and postal code information along with current location identifier	This map shows an aerial view so that users can select different locations on the streets for recording conflicts. User should be able to use their current location for recording conflicts.
3	Location Search	The map view also comes with a location search options where users can type in zip code of location address	The application should provide user interface to search particular location using the map view and able to locate the location by Zip code or address
4	Local Storage	Application requires showing images and GIFs to user to make the user interface more intuitive. These images and GIFs are associated with different survey question of the app.	Images and GIFs are stored on internal storage of the application to show when appropriate
5	Search Conflict	The application equips the users with a user interface that provides menu options used to search conflicts by zip code or by distance in miles. Users should be able to see conflicts recorded by themselves, as well as by other users.	The application should provide a way to search conflicts recorded by different users Possible filters for searching conflicts include 1) user's own conflicts, 2) all conflicts recorded in area by zip code, and 3) all conflicts recorded in area by distance in miles. Zip codes and distance in miles are user-entered values.
6	Recording a Conflict/Activity	The app should provide a smooth interface for the survey questions for recording any conflict or activity.	The user should be able to answer a set of predefined questions for recording a conflict or an activity
8	Interface to Cloud Storage	When prompted, conflict records from the cloud storage can be seen on the map view of the app	Conflict data is stored on Amazon cloud database in this application. This application manages create, read, write, update operations on this remote database.
9	Data Subscription service	The application's user interface shows all conflicts by search filter in text format or in a map.	This application should provide interface that can access information in CSV (88) or KML (89) file formats, which can be downloaded and shared.

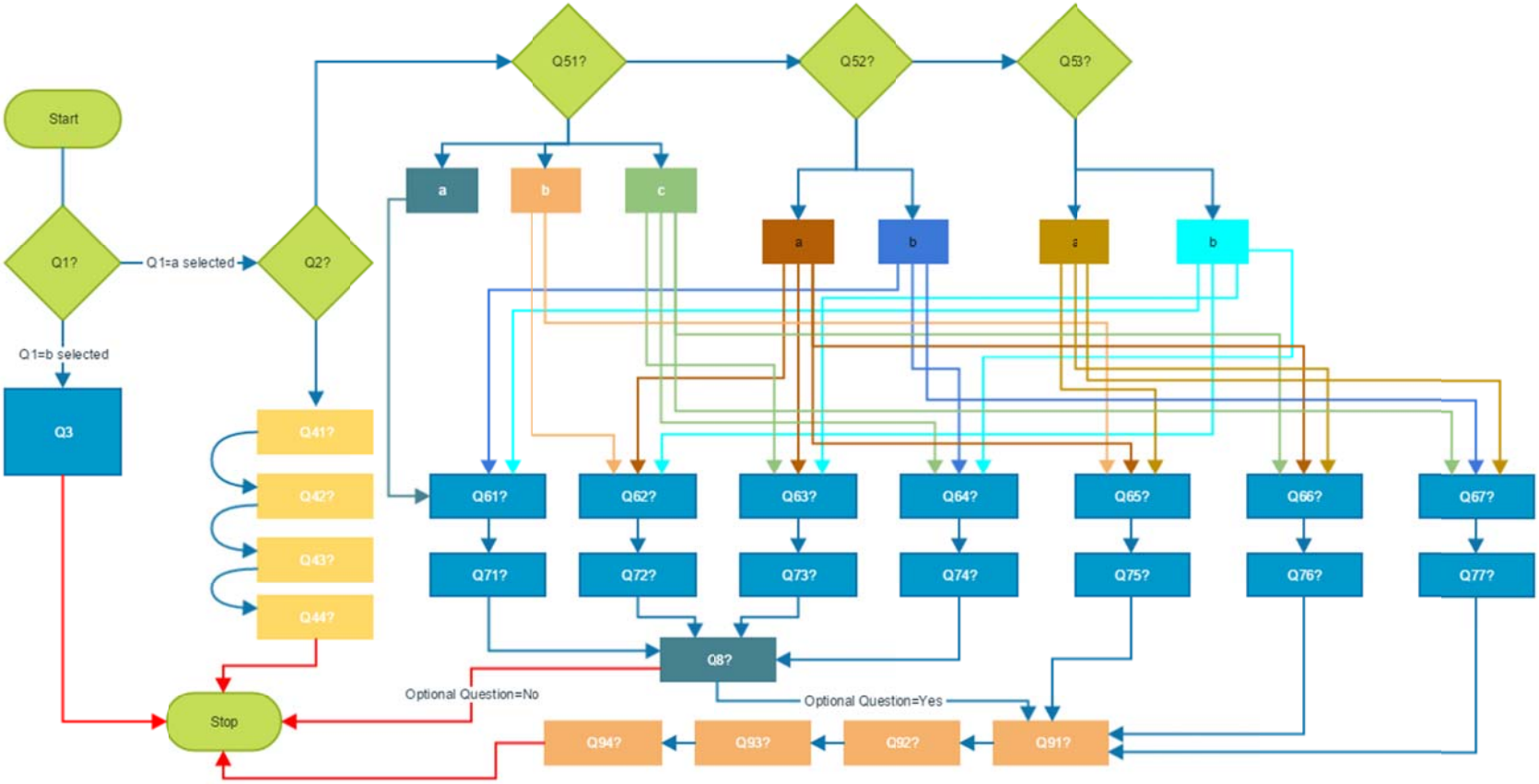


Figure 2 Flow Diagram for Survey Questions (Appendix E)

5. App Development

This app development section lays out the development process of the app based on numerous brainstorming sessions of the research group for achieving requirements set by feedback from the prototype testing and focus group survey. The development process includes steps for development from the prototype phase to the production version.

5.1. Development of prototype

At the beginning of the project, the research group developed the prototype of the application and tested it to get initial feedback. The prototype had a simple user interface, including the map view and the survey used to record conflict information. The recorded data was downloaded as a CSV format file directly from the AWS Dynamo DB service. This prototype was developed from the feedback of the initial app user and end user focus groups. The research team conducted the initial prototype rollout in spring 2016 with the assistance of the students enrolled in the introductory class of Transportation Engineering, which is listed as CE 3302 at UTA.

5.1.1. Development of simple user interface for recording conflict data

The first stage of the prototype development tackles simple user interface, which gives the user a way to record data through the map view and survey interface. The cloud interface that was developed updates this data into the AWS Dynamo DB database (90). Figure 3 shows the user interface created during this stage. The prototype user interface enables a user to record a conflict with information, such as the description, type, date, time, location, and severity of the conflict, using map control on the app's home screen. Each conflict record is shown on the map view of the app with basic information (such as type and location of conflict) associated with it.

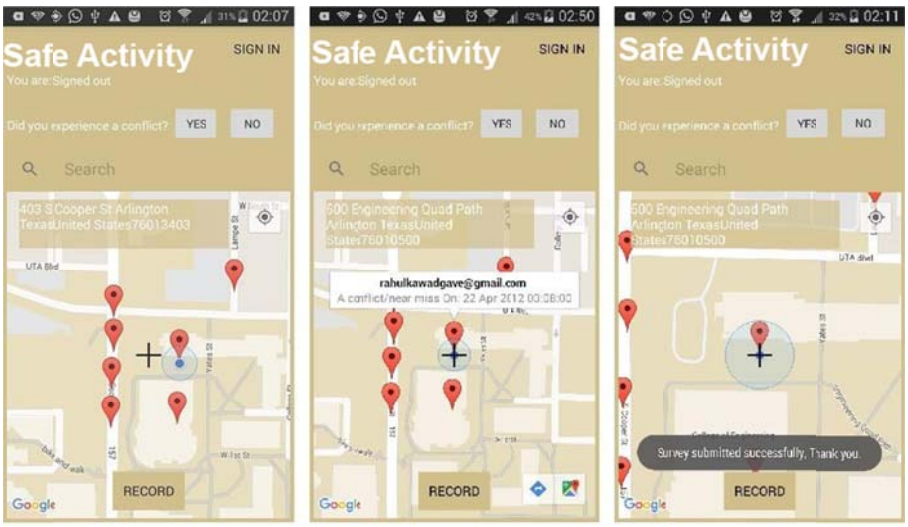


Figure 3 Prototype Version User Interface

5.1.2. Testing and Results

The prototype application was made available to students for download and use (91) on the Google Play Store. After the testing of the app by the student users for approximately one month, the developers analyze the recorded data and feedback survey from the users for potential errors and future modifications. Figure 4 shows the database snapshot of the recorded data by the students. The prototype app represents the idea of the potential application to the focus group and hence recorded data in the prototype stage in not fully completed as per the requirements.

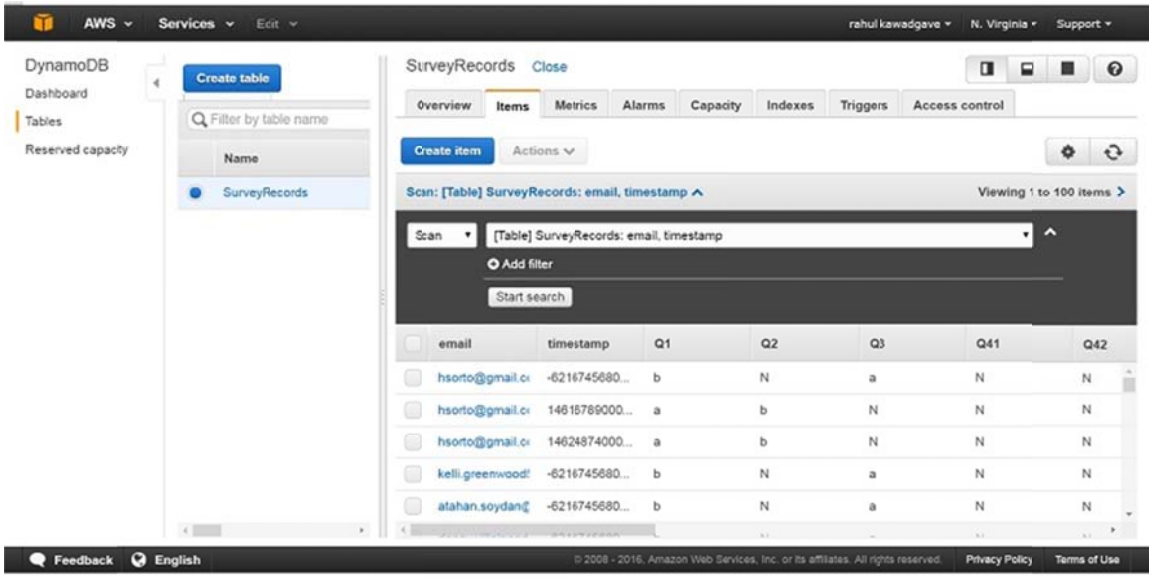


Figure 4 Prototype Version Cloud Database View

5.2. Main Software Architecture

This software architecture contains two main components, mobile application and cloud services. The mobile application will collect the necessary data from user inputs as per the requirements and upload the collected data to the cloud-based database. The mobile application also interacts with the cloud-based database service and queries data when required. This interaction occurs between the querying database with different search queries generated as per the requirement by the user. The application also uses cloud services provided by Google. The mobile application contains a user interface and the interface to cloud-based database service. The user interface includes a map view, survey user interface, list views, and menu options for the users to sign in and search. The interface related to the cloud-based database service utilizes an Amazon Dynamo DB mapper package (92). Dynamo DB mapper provides a simple and easy way to access the cloud-based database in AWS. The Mobile Application also connects to the Google cloud to use services like Google Maps (93), Sign in (94), and Location APIs (95). The AWS cloud database contains tables created to store conflict information and user group related information. Google client APIs provide a way to connect to the Google cloud services. Figure 5 shows the different components of the software architecture in detail.

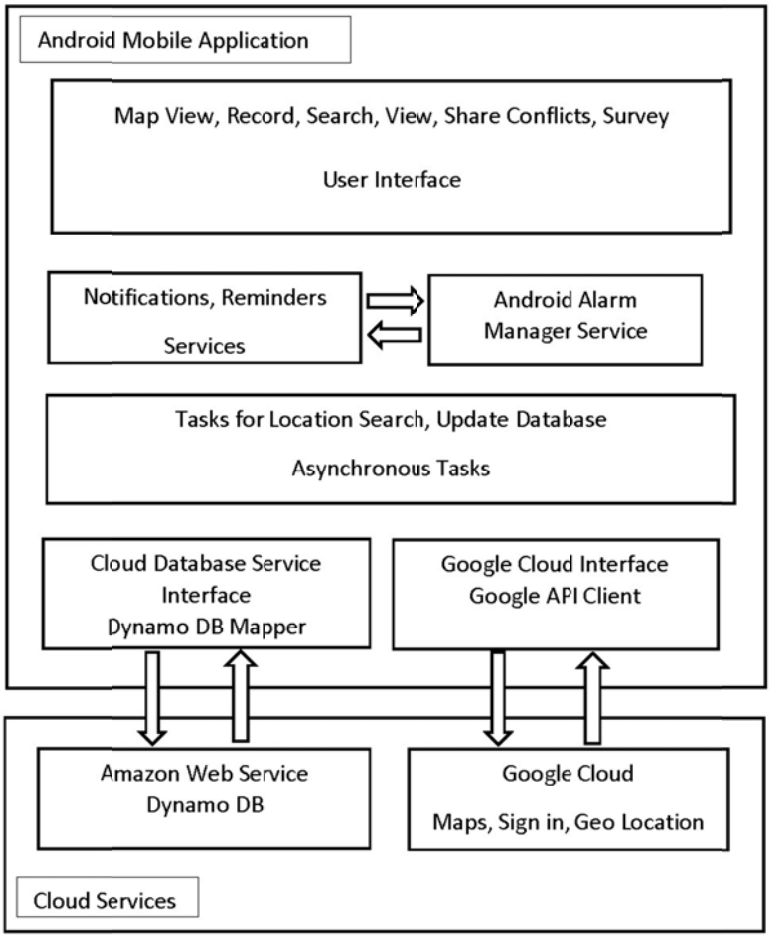
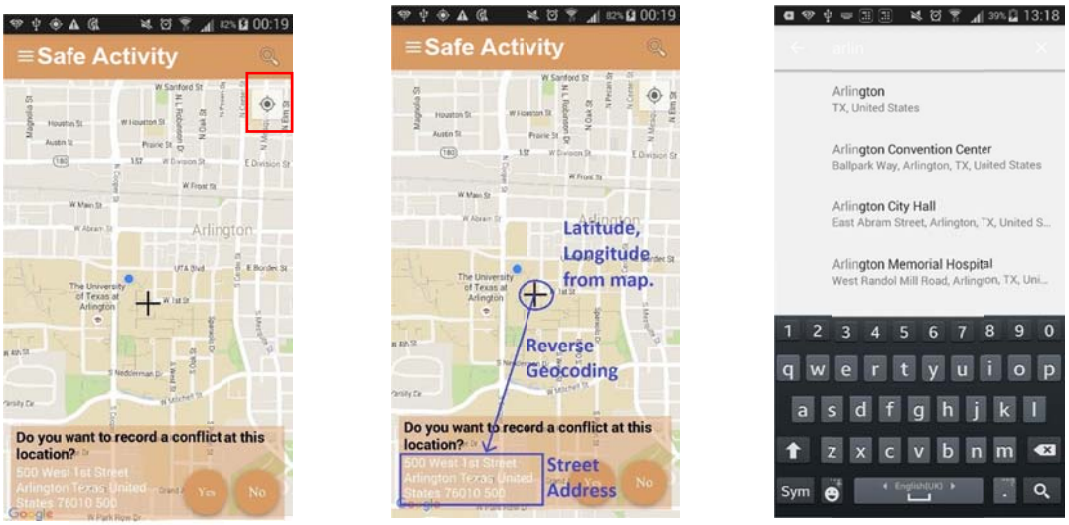


Figure 5 High-level Block Diagram of Mobile Application

5.3. Detailed Design and Implementation of Mobile Application

5.3.1. Location Information

Functionalities, like the record, search, and user reminder notification, make use of the user's location and location services. Firstly, this application, in particular, uses the location services application program interfaces or APIs to know the user's last location. Google Maps for Android provides inbuilt features, which helps a user to move the map view to its current location (96). Figure 6 (a) shows the button in right-top corner just below the search button. The user's last location is required in this application to notify the user about conflicts in the current area and within a certain distance of the user's current location. This API provides location in terms of geographic co-ordinates latitude and longitude. Secondly, a geocode class is part of the Android framework location APIs (97). This class provides two important functions: 1) Geocoding 2) Reverse geocoding. Geocoding is the process of converting a street address to latitude and longitude i.e. geographical coordinates. Contrary, reverse geocoding converts geographical coordinates to a street address. This application uses reverse geocoding to display the current address on the home screen when a user moves the map view to any particular location (Figure 6 (b)). Lastly, a place autocomplete service in Google Places API provides the list of places in return to a user's search query (98). This application uses the option launching autocomplete activity using intent. The Activity returns the results to parent activity using Place is an object that provides information like geographical coordinates. Figure 6 (c) shows the place autocomplete activity with a list of places searched by the user.



a b c

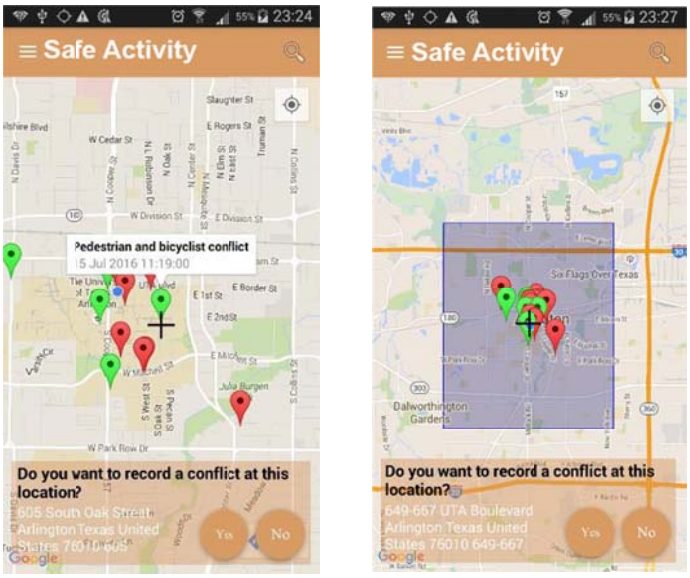
Figure 6 a) My Location Button, b) Geocoder View, c) Place Autocomplete activity

5.3.2. Google sign in

The user identification in this application uses Google Sign-In for Android devices (94). Users with Google register every Android device. By using the Google Play Services API client in Android, the Google Sign-In feature may be integrated into any application (94). Google services provide a configuration file that is needed to integrate into the application in order to get access to Google Sign-In, which in return provides access to the application. This file contains information, like API access related keys and authentication information, used to create a client id with Google, which is necessary for use in this project. This application, in particular, utilizes the app user's email id as an identification parameter for each conflict recorded and provides the user's full name in the user interface. Using Google Sign-In for Android provides an automatic and secure registration system that is used by various devices and users. In addition, the Silent Sign-in feature enables the application to "silently" sign in using previously granted authorization (99). Whenever the user launches the application the silent sign-in feature allows a user to sign in immediately and retrieve profile information. If there is no user authorization previously done on the device, the user application provides sign-in options again to a user.

5.3.3. Google Maps

The Google Maps Android APIs make adding Google Maps to an Android application possible (93). Google Maps APIs in Android uses Google Play Services SDK. Installing and configuring the Google Play services SDK provides access to the application. The application should also be registered in the Google API console in order to get a Google API key, which will be added to the Android project. With respect to mapping needs, Google Maps provides a way to add markers and shapes to the map view. Google documentation for developers provides online systematic help to add Google map view to an Android application. This application's map view provides users the access to record a location and then view recorded conflicts using markers. Map view also serves as the home screen for the application (Figure7).



a b

Figure 7 a. Drawing Marker; b. Drawing Small Snippet

Map View provides a way to record a conflict at a particular location and then use the search button on the top-right corner to search any location by name, zip code, street name, and address. Map view also provides an option for "my location" to center the map view to the current location. The map view is also used to view search results. Users can search conflicts using three primary filters using the menu options. The map view can also be used for placing markers when recording a conflict. These markers will be displayed with different colors, which correspond to severity levels (100). Figure 7 (a) shows different markers drawn with info windows. The Marker Options (101) class in Android provides functionality to state the position in latitude and longitude, icons with colors, title and small snippet as shown in Figure 7 (b). Lastly, Google Maps Android API also provides map animations using the map view where it can adjust to different zoom levels or tilts and panned (102). LatLang and LatLangBounds classes are used to adjust and provide a different set of points on the map for animations (103, 104).

5.3.4. User Interface Views and Controls

This section describes the view and controls available in Android and used to implement this application. Table 3 lists the views and controls used to build different components in this application.

Table 3 User Interface Controls

	View/Control	Components
1	Activity	Home screen, Survey screen, Share screen
2	Fragment	Survey questions, Map View, GIF Player, Location Search view
3	Alert Dialogs	Popup dialogs, Error Dialogs, User Inputs, and Confirmation messages.
4	Snack Bars	Showing alerts, messages to a user.
5	Image View	Survey screens to show extra information
6	Navigation Drawer	Navigation drawer is the navigation options displayed on the left side of the screen
7	Recycler View	List view on the share screen.
8	Date Picker	Date picker view in survey screens.
9	Time Picker	Time picker view in survey screens.

5.3.5. Survey Design

Conflict information is recorded in the application with the help of survey questions as mentioned in the requirements. Users are asked a set of questions regarding the conflict, which will be recorded in the database. The visual representation (i.e. jpeg or gif) of these conflicts along with exact definition and variable categories are followed from Casey et al. (2016), which was developed by the team from the feedback of the two focus groups mentioned earlier. The SurveyRecords class represents the one record generated after a user enters answers to survey questions in one flow. The SurveyRecord is converted to the database mapper class used by DynamoDBManager class. The Survey user interface creates dynamic screens generated as the survey flow goes on a particular path with each question answered. Android provides a Fragment view, which holds a piece of the user interface (UI) (105). One Fragment viewed as part of an Activity in Android. The survey uses one Activity and list of fragments to show questions on that Activity using FragmentManager (106). It is possible to create a stack of fragments in Activity, which supports push and pop operations. Using this stack, the survey UI implements the next and previous operations.

5.3.6. Notification Service

Notifications and reminders as per requirements use different Android framework utilities provided for implementation. Figure 8 shows the details on design for the generation of notifications and reminders. Application sends notifications to the users when anyone records an incident in the nearby vicinity and sends a daily reminder to record a conflict.

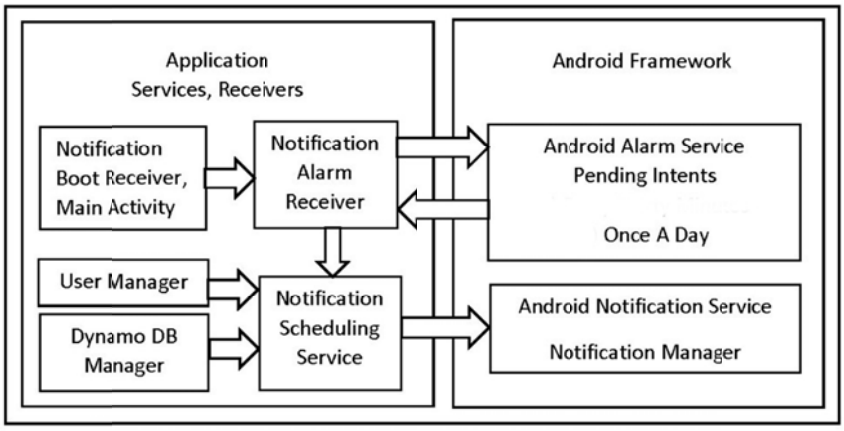


Figure 8 Notification Service Architecture

5.3.6.1. Notification Alarm Receiver

Notification alarm receiver interacts with the Android Alarm Manager in Alarm service and registers two alarms using Pending Intents as shown in Figure 8 (107, 108). Application components boot receiver and launcher activity of application register alarms using pending intents to the Android Alarm receiver. A Pending Intent is a way to communicate with existing services in the Android framework.

Pending intents registered with the Android alarm service will call the handler in the application's notification alarm receiver. This receiver is a type of WakefulBroadcastReceiver in Android (109). This will wake up the device whenever an alarm triggers off and even if device is in sleep mode.

5.3.6.2. Notification Boot Receiver

The Notification boot receiver with the help of a notification alarm receiver registers the required alarms with the framework in case of device reboots. The Boot receiver implements handler, which triggers in the case of device reboots. This step is important as the application exits when a device shuts down and a user may not launch the application every time after reboot to register the alarms required (110).

5.3.6.3. Android Alarm Service

Scheduling repeating alarms with Android alarm is an easy procedure (111) because Alarm manager APIs remain simple to use. There are several ways and types to register alarms on Android device. The alarms used in this application are real time wake up as the application requires showing notifications even when the device is in sleep. Repeating alarms are in Android can be exact or inexact. The inexact alarms used in this case allow the Android framework to manage power better by aggregating requests from different applications and wake up the device at a single point in time to serve them all together. Setting an inexact repeating alarm type will also help and not burden the cloud-based service. This will also largely help to avoid the concurrency issues with cloud-based services.

5.3.6.4. Notification Scheduling Service

The notification scheduling service will handle the requests from the Notification Alarm Receiver to actually queue the notification with the Android framework (112). This service runs in the background and handles the intent from the alarm receiver once a day. It takes the decision whether to show a notification and reminder depending on the application's current user and user group. The service uses the user manager and Dynamo DB Manager to get information about the capabilities of the current user.

5.3.7. File Writers

The application provides a way for end users to download and share conflict records using both CSV and KML file formats. Created files appear in the external directories. This directory is temporary and external to the application. In this case, files created are shared with other applications such as the Gmail, Dropbox when a user selects the share option. The system takes care of deleting files in an external directory when the user uninstalls the application or when the system requires more space. A user has an option to choose the download format as either CSV or KML. The CSV format file is created as per the columns and rows specified in the requirement. The KML file format opens in applications like Google Earth and the application implements the KML writer to create this file format.

5.3.8. Cloud-based database

This application uses a cloud-based database service to store all conflict data recorded by the user and all of the application users' and groups' information. Figure 9 shows the application's components and interface to cloud in detail. The cloud database used in this application is Dynamo DB. This section describes the configuration and interfacing with Dynamo DB from the Android application.

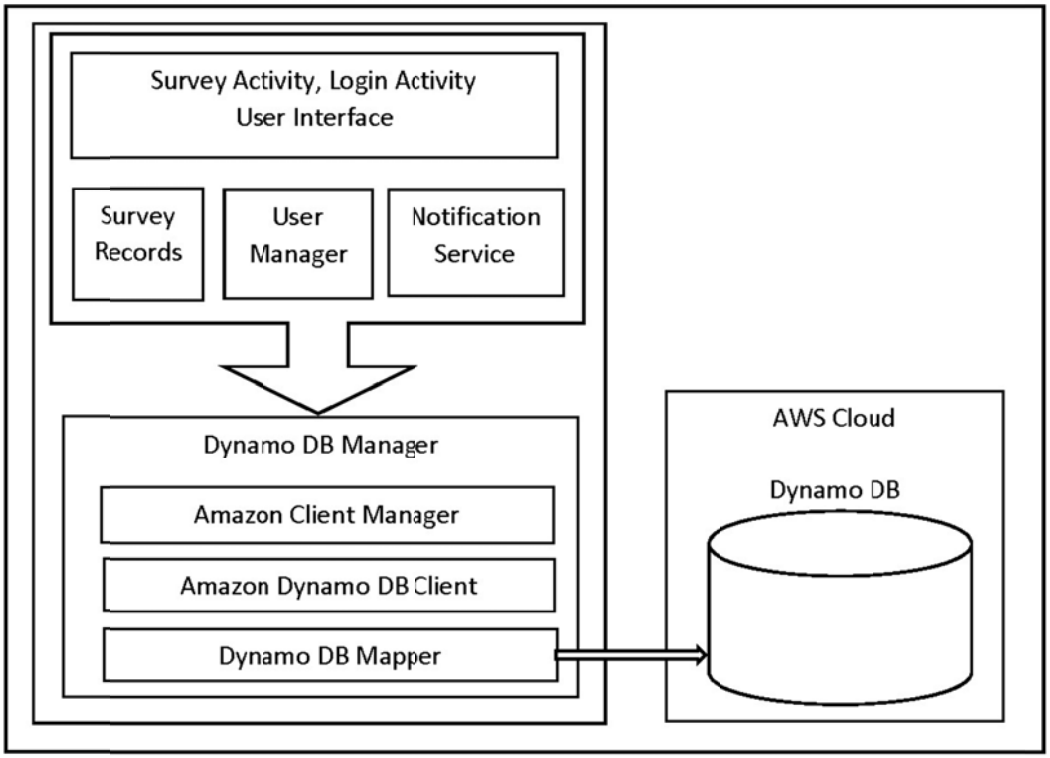


Figure 9 Architecture of Interface to Cloud

Dynamo DB is a NoSQL database service and it is a simple way to get a fully managed database running in a short time. As this application requires a secure and easy to handle database service, Dynamo DB is a quality option because it provides what is needed. Amazon also provides different access controls to each table created in Dynamo DB. Authentication and access control for Amazon Dynamo DB uses credentials as part of AWS Identity and Access Management (90).

Dynamo DB is a NoSQL database as described in Amazon documentation (113) and provides the high performance needed for real-time applications and on devices like those that mobile phones use. The APIs that are used to store and retrieve in Dynamo DB are object based, which mean that the development becomes easier for the app creators. The data model is key-value based, and the values are retrieved in the form of JSON, XML. The data model is also schema-less in Dynamo DB, which makes storing the records derived from the survey that takes different paths easier; not every record stored in the database has data for every key in the database.

The application stores conflict data and user group related information in this cloud database. Three different tables handle this requirement, and the access to these tables uses the Dynamo DB Manager. This interface enables the application to create, read, write, and update different records in these tables. Figure 10 shows the databases created in Dynamo DB. The database tables have all the information described as part of the requirements of this application. The Dynamo DB Manager provides service to the different components in this application to provide access to the database. The survey records use this interface to store conflict information in the database, whereas the notification service and the user manager need the application user group's related information from the database. The Dynamo DB Mapper class is the interface to the Dynamo DB from application. The Mapper provides direct access to the DB from the application and provides different operations like save, delete, and scan on the tables. The Dynamo DB

also provides different ways to scan and query the database using the Dynamo DB Mapper class. This application uses the filter expressions to search different conflict records from the database.



Figure 10 Dynamo DB tables.

5.4. Data subscription service

Data subscription service in this application provides an interface for users to the data recorded using application in the cloud-based data store. The application provides an interface to data for users two ways 1) Visualization of the data using Google Maps, Google Earth application 2) Download and email the data as a file with the format as CSV or KML.

Users with permission as defined in the application user groups will be able to access the data from the AWS Dynamo DB service, download the data and share it. As shown in Figure 11, a user can search the data and export it to a CSV or KML file, this access is only given to Admin users.

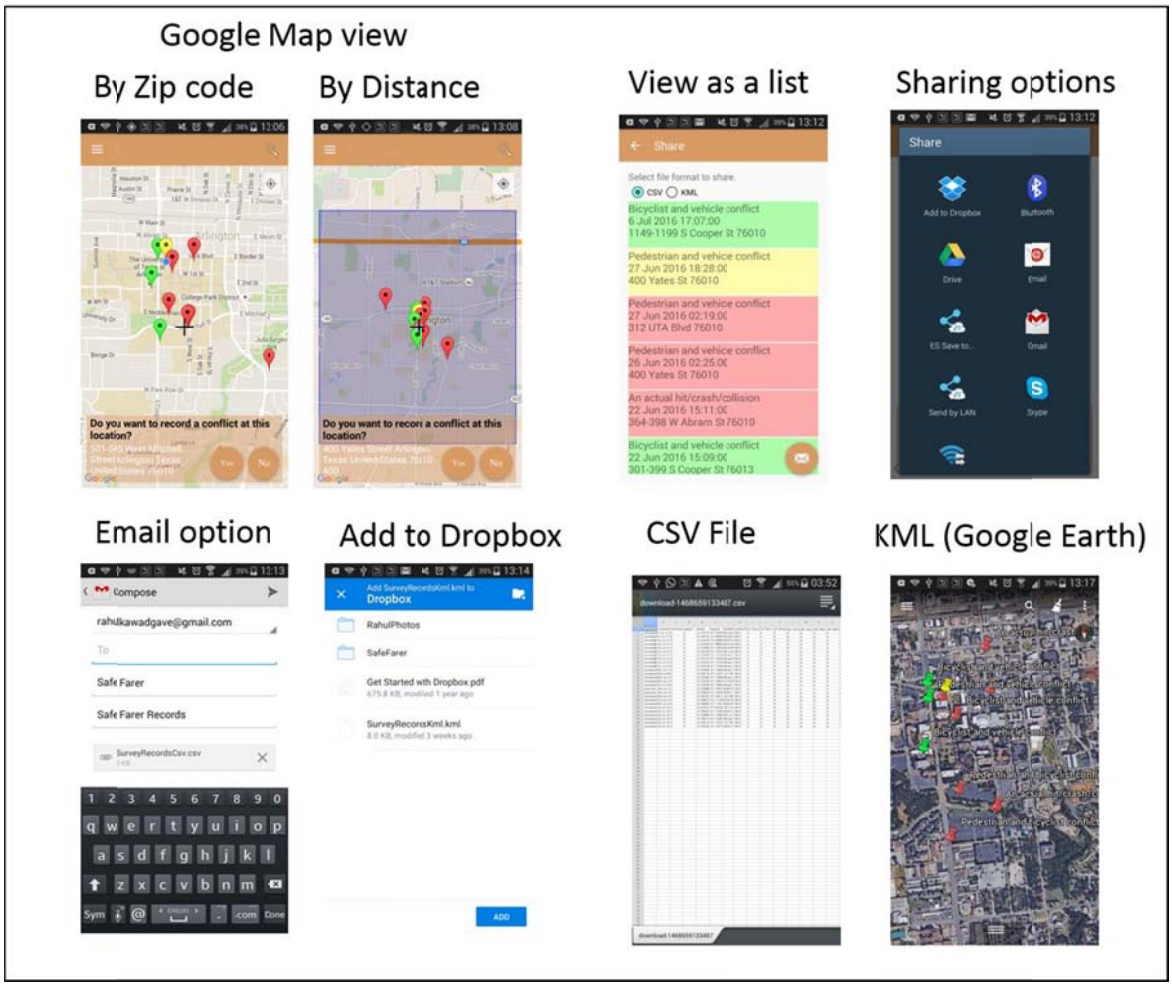


Figure 11 Data Subscription Service User Interface

5.5. Verification and validation

Verification means the product has been developed well whereas validation means does the product actually achieve its goals and function properly. Verification involves activities like ensuring the product is being built in line with the required specifications; it also includes reviewing requirements and updating requirements to include feedback from different elements like internal and external reviewers. Validation involves testing the actual product to ensure that it works correctly as per the requirements and design.

Verification for this product includes developing a prototype from initial requirements and receiving feedback from different focus groups and UTA students testing the prototype. The internal team uses this feedback to refine and verify requirements. To some extent, verification also includes the manual testing of the prototype application with some primary test cases. Validation testing happens on the production version of the application with the test plan mentioned in this section. This section documents the test setup involved to test the prototype and production versions of the applications.

5.5.1. Test setup

Setup includes Android devices with different versions of Android installed to include all supported API versions, applications permissions, and screen sizes. Table 4 shows different devices used for testing this application.

Table 4 List of Devices Used for Testing

	Device Name	Android version	Quantity
1	Samsung GT-N7100 - Phone	4.4.2	1
2	Google Nexus 7 - Tablet	5.0.2	1
3	Google Nexus 7 - Tablet	6.0.1	1
4	Motorola Moto E - Phone	5.0.2	2

5.5.2. Testing

Table 5 shows the overview of some manual/automated and positive/negative test cases run as part of the unit/regression test phases/plans.

Table 5 List of Test Scenarios

No.	Test scenarios
1	Launching application with location settings enabled/disabled.
2	Launching application with internet connectivity settings enabled/disabled.
3	Tested working on survey user interfaces for different possible combinations of user inputs.
4	Recording conflicts of all combinations possible and check cloud database updated with expected information recorded.
5	Test application users and groups information updated properly in cloud-based database.
6	Test with every new installation user assigned with expected user group as per requirement.
7	Test notifications and reminders generated using set of devices mentioned in the setup.
8	Test AWS Dynamo DB interface for handling of requests and response scenarios using automated/manual tests for different scenarios.
9	Test data subscriptions services like CSV and KML files generated as expected using share menu options provided.
10	Devices having different emails logins application users and user groups are tested.
11	Different searches of conflict records from database using zip codes, distance requirements tested using manual using menu options in user interface and automated using test stubs in source code.

5.5.3. Bug fixing and Issues faced

5.5.3.1. GIF Rendering

GIF rendering in this application requires hardware acceleration in the disabled mode. Starting with Android 3.0 the GPU can perform drawing operation on the view's canvas. By default, hardware acceleration is enabled, which forces the view rendering to use GPU. This application in the survey user interface displays GIF animation to make the user interface more intuitive for the user to understand the conflict scenarios. The GIF file sizes provided were large in size and GPU rendering did not work as expected. Therefore, this application uses hardware acceleration in the disabled state to avoid using GPU to render the GIF animations.

5.5.3.2. View Pager Vs Fragment Manger in survey user interface

The prototype version of the survey user interface uses View Pager, which also supported left-right swipe functionality to navigate through survey questions. As this survey interface requires the user to move to the next questions only when the user answers all currently displayed questions and the left-right swipe functionality in View Pager control cannot be disabled, this View Pager control for the survey does not meet the requirements. Instead, the Fragment Manager APIs easily handle different operations on fragments and provide a more advantageous survey user interface.

5.5.3.3. Android permissions

The Android system permission model (114) has updates starting with Android 6.0. The application is required to check run-time permissions from a user along with file permissions mentioned in the manifest file of the application. One such issue is identified and fixed. The implementation for permission to show "my location button on Google Map View" was updated to be in line with this new requirement of the Android Framework.

5.5.3.4. Notification service

The notification service is dependent on a Google API client connection (115). A Google API client connection is possible in two ways: synchronous and asynchronous. The notification service was using an asynchronous way to connect, which caused the service to miss showing notifications. The implementation is changed to connect the API client in a synchronous way using a blocking connect method for the Google API client.

6. Experimental Design

6.1. Training Materials

The research team has developed a demo tutorial video and a PowerPoint presentation for the app users that explains the different features of the app and guides a user through using it. They have also prepared a manual that explains the definition of the conflict categories and their severity level (**Appendix F**). A comprehensive knowledge of the manual will help users understand variables included in the conflict analysis used in the app survey questions.

6.2. Application Users and Groups

This section documents the requirements related to the mobile application users and groups. One of the research requirements of this experimental design is that application users are divided into different user groups so that application usage for different scenarios can be evaluated. The user groups are differentiated based on providing 1) a daily reminder, 2) a notification for a conflict recorded in the user's area, 3) view

conflicts recorded by user, 4) view conflicts recorded by other users, and 5) download conflicts as a csv/kml file (Table 6). Users in Group 0 are all with role admin and GROUP 1, GROUP 2, and GROUP 3 are granted with a limited capability role as other.

Table 6 Different User Groups and their functional capabilities

Group	Role	Gets Reminder	Gets Notification	View Own conflicts	View Other Conflicts	Download Conflicts Database (CSV/KML)
Group 0	Admin	Y	Y	Y	Y	Y
Group 1	Other	-	-	Y	-	-
Group 2	Other	Y	-	Y	-	-
Group 3	Other	Y	Y	Y	Y	-

6.2.1. Reminders and Notifications

The research project seeks to determine if daily reminders and instant conflict notification motivates users to use the app more frequently. For this reason, the researchers have created three user groups as previously described. The user groups (1, 2, and 3) have different reminders and notification strategies associated with their respective groups. The reminders would be a daily occurrence, asking "Would you like to report a conflict today?" If a user clicks on the reminder, it should open the application to show the apps home screen with the map view. Every thirty minutes, when a conflict is recorded in that user's area, then the user receives the notification. The current postal code area represents the current area. The message shown in the notification would read "one /more conflict/conflicts was/were reported in your area".

6.3. Methodology

The research group selected twenty-six different elementary schools from the Arlington Independent School District (ISD) for the data collection process. The Introduction to Transportation class at UTA completed their class project in two phases. In the initial phase, each group (at least a group of two) collects inventory data of the infrastructure elements in their specific school census block, which may encourage or discourage walking and biking. Later in phase two, each group identifies the busiest area on the street, whether it is an intersection or a segment and collects four hours of conflict data. Students perform this phase during peak hours. Most of the groups visited their corresponding site four times and each time collected approximately one hour of data. The students can also use the app in their day to day activity. Students have the option to either collect their own conflicts while walking or biking or they can also be an observer at critical locations and record the conflicts experienced by others.

In addition to the students, the research group also reached out to the agencies and organizations identified during the previous stakeholder focus groups; the team uses both emails and phone calls to encourage participation in the app testing. The team also contacted the Arlington ISD Parent Teacher Associations and collaborated with the Fort Worth Blue Zone project in a voluntary effort to help a walking school bus. The team also announced a compensation/prize of $50 for the most frequent users.

6.4. Experimental design outcomes

At the end of the data collection period, the research team downloaded the data from the cloud storage (SurveyRecords.csv) and formatted the data into an Excel file. A set of 129 conflict records are stored in the database after the research team deleted several records, which were executed during the development

process by the admins for debugging the app. Out of these conflict records only 9 records happened when a vehicle or a bicyclist has overtaken a bicyclist or a pedestrian respectively. Based on the transportation infrastructure within Arlington, the city lacks shared bicycle lanes around elementary schools. The other 120 conflicts are non-overtaking conflicts. As only students took part in the data collection process, they mostly remained in their school zone areas, which evidently do not have any shared trails for bicyclist and pedestrians. Almost 67% of the overtaking incidents are among bicyclist and vehicles and the rest occur between bicyclists and pedestrians. On the other hand, 83% of the non-overtaking conflicts (120) are pedestrian-vehicle conflicts whereas bicyclist-pedestrian conflicts are at 9% and the remaining 8% are bicyclist-vehicle conflicts (Figure 12).

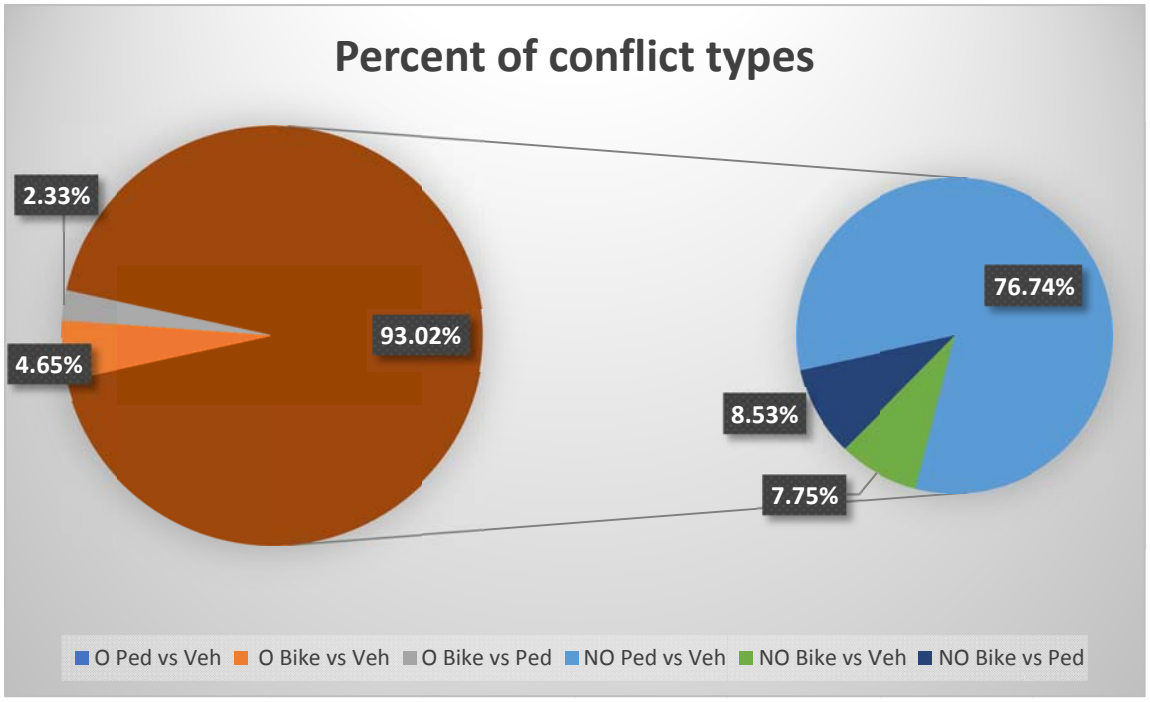


Figure 12 Percent of Conflict records for five different categories

6.4.1. Severity Level Analysis

When Casey et al. (2016) developed a conflict analysis performance measure as a surrogate safety measure, they defined four different severity levels (Table 7). Almost 36% of the conflicts recorded by the students appear to be a serious conflict (category A), which narrowly avoided collision. Almost 9.3% of the conflicts recorded fall into category B where incidents have a significant potential for a collision but may be avoided with a time critical response. A category C conflict means that the conflicts do not appear extremely severe and the incident can be avoided with moderate time and/or distance available to the parties involved. Almost 31% of the non-overtaking conflict falls under this category. Finally, the remaining 17% of the conflicts identified as category D likely have no immediate safety consequences (Figure 13).

Table 7 Conflict category and their definition

Category	Category Definition
A	It is a serious incident in which a collision is narrowly avoided
B	It is an incident with significant potential for a collision where separation decreases and incident may result in a time critical response to avoid a collision
C	It is an incident characterized by moderate time and/or distance to avoid a collision
D	It is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single vehicle/person

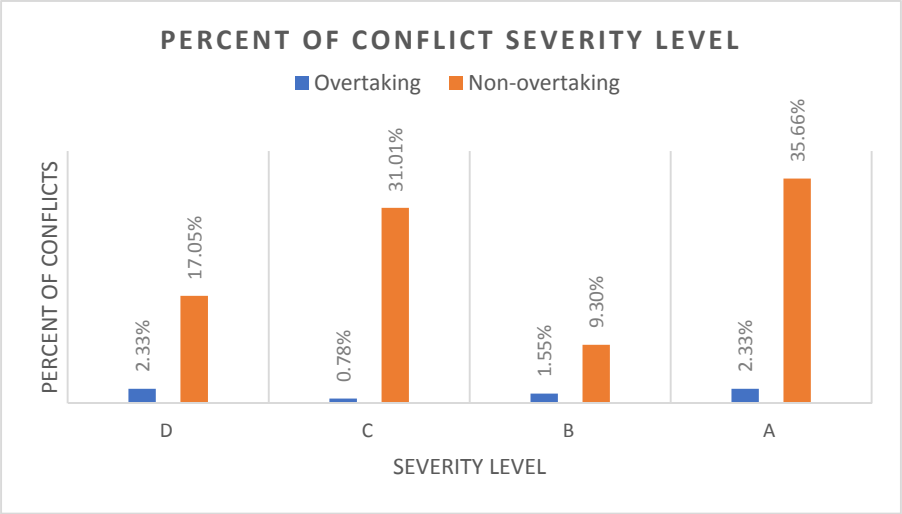


Figure 13 Total percentage of conflict records and their severity level

Out of the total overtaking conflicts, the total percentage of bicyclist- vehicle conflict in category A and D are the same (22%) whereas the percentage in category B and C are the same (11%) (Figure 14a). The lack of data for overtaking conflicts makes drawing any definitive conclusion difficult. A more detailed data collection in areas of shared path usage may improve and provide more details into this facility type.

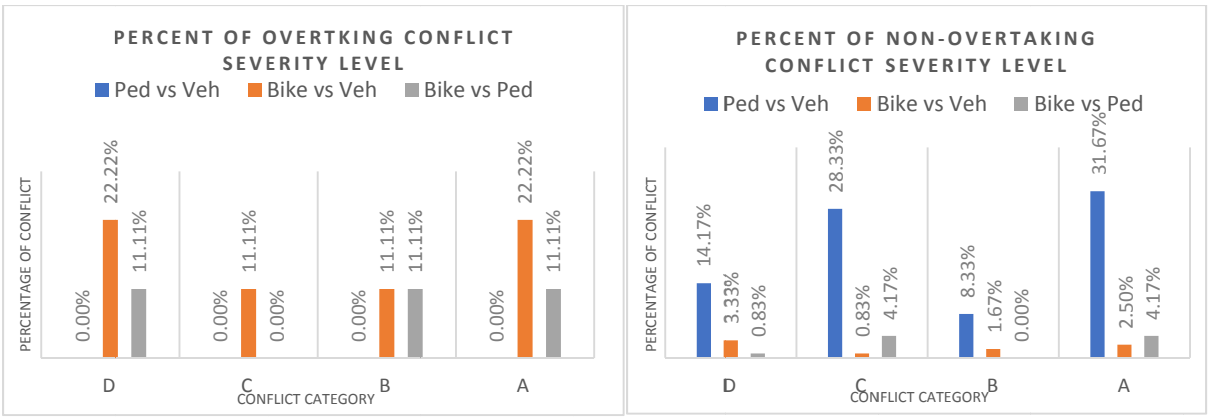


Figure 14 Percentage of conflict records; a. overtaking conflict, b. non-overtaking conflict

On the other hand, almost 32% of the non-overtaking pedestrian-vehicle conflicts are narrowly avoided collisions and hence fall under category A. The second highest number of pedestrian-vehicle conflicts falls under category C, which has the potential of being a collision but may be avoided if moderate time to make a reaction is available. More than 14% of the pedestrian-vehicle conflicts fall under category D and about 8% falls under category B. Almost 3.33% of the bicycle-vehicle conflicts fall under category D. More than 4% of the conflicts occurring between bikes and pedestrian fall under category A and C. Additionally, less than 1% of the bicycle-pedestrians conflicts are identified as category D which is very negligible due to having very less number of observations (Figure 14b). As mentioned earlier, the observation areas near elementary schools appear to have limited bicycle use along the sidewalk or on the streets, so the total percentage of the conflict bicycles remain less than 10%. Also, due to the fact that almost no designated bicycle lanes on the street exist in these areas, the percentage of conflicts between these two parties remains low.

6.4.2. Hot Spot Analysis:

Identification of hazardous locations or black spots or hot spots or collision-prone sites is a systematic process for distinguishing high risk road segments or intersections that suffer from crashes. This method is not only a cost-effective countermeasure, but it also helps prioritize specific treatment sites. This same concept can be used to identify hot spots for conflicts, which will eventually reduce the chances of collision occurrence in that area. K-mean clustering [116,117], nearest neighborhood hierarchical (NNH) clustering [118-120], Moran's I Index, and Getis-Ord Gi statistics [121-123] are some geostatistical methods available to evaluate the relative risk based on their degree of association with their surroundings. But here as a basic example, the research team uses a simple distribution-based clustering (124).

Four years of pedestrian and bicyclist fatality data are collected and mapped on the previously downloaded Google Earth file using this ⊘ sign. From the limited data collection during the field test, the research team matches four different geo-spatial hotspots where the users recorded a certain number of conflicts at these sites. Due to the uncertainty of crash occurrence and hence the limited data on crashes and fatalities, the total number of crashes for this example may not identify the comprehensive nature of the hot spot analysis. However, the research team found at these four different locations where previously a pedestrian or bicyclist fatality occurred that the users have identified a category 'A' conflict at one location and category 'D' conflicts at the other three locations. This outcome indicates that the limited data collection effort provides some mapping to locations that have produced fatalities in the past (Figure 15). A more in detail analysis of hotspot and crash location matching remains critical for future crash

predictions and identification of the failure mechanism; however, this will require a more significant market penetration and corresponding community use of the app. The research team has established an example for the end users, which guides them through a step by step procedure to separate data in Google Earth for an area specific conflict analysis (**Appendix H**).

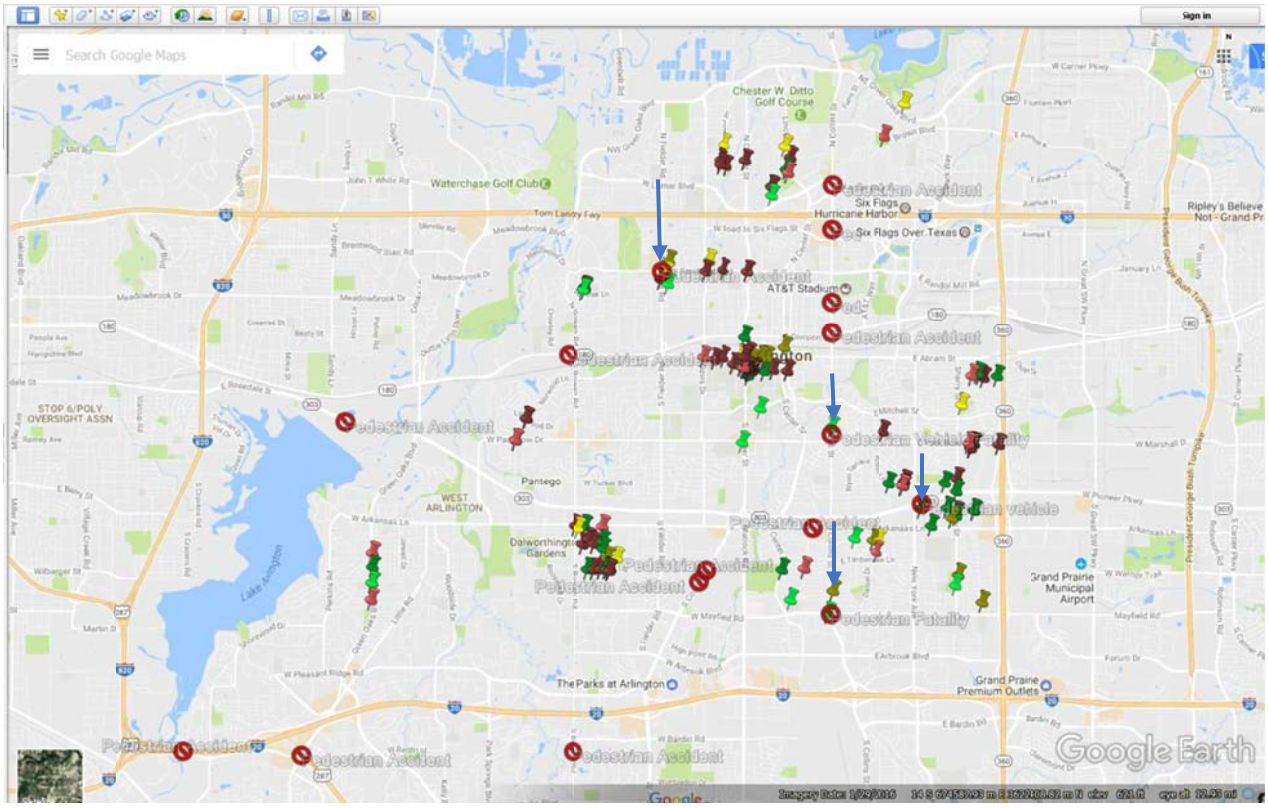


Figure 15 Hot Spot of Fatal Crashes and Clusters of Recorded Conflict

6.5. Feedback Survey

The researchers prepare and administer two different surveys for app users and end users using a set of Likert scale and open ended questions (**Appendix G**). After the end of the one month of app testing, the users provided feedback about their experience of using the app. Survey logic is used to ask a minimal number of questions to different groups of users (Table 6) as identified by the initial app sign-in. After the end of the survey period (10 days), the research group contacted the remaining "users" who had downloaded the app to try to solicit additional feedback. At the end, only 41 total app users completed the survey.

The survey uses a set of questions, which cover the overall competency of the app interface and the performance of its features. Examples of sample questions include:

- I can answer the questions easily
- I was able to accurately determine the location of conflicts
- The notifications provided via the app encouraged me to use the app in timely manner?
- How likely will you suggest the app to your friends?

While some of these questions are designed using a five point Likert scale, others are just yes/no or open ended questions. Figure 16 presents the percentage of users agreeing or disagreeing on certain features of the app.

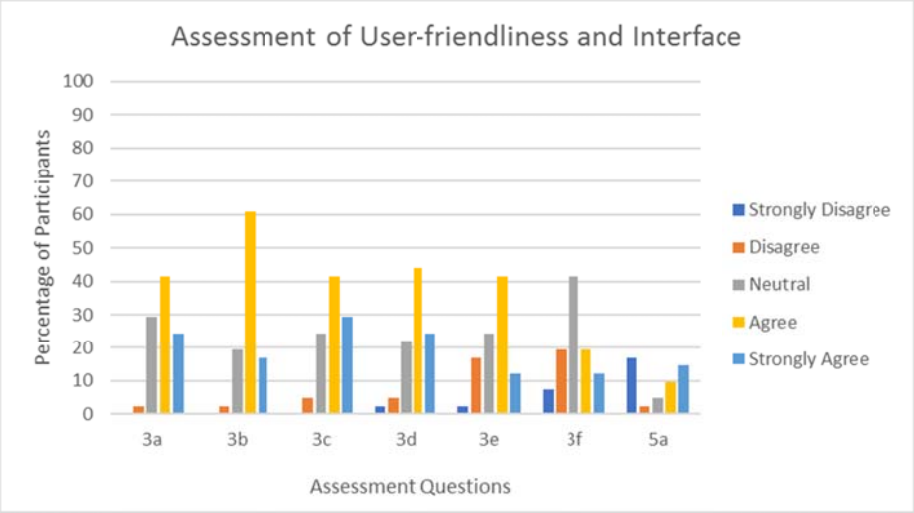


Figure 16 Percentage of participants agreeing/disagreeing on user-friendliness

6.5.1. User-friendliness of the App.

The research group performed a comprehensive literature review on conflict analysis and adopted the performance measures developed by Casey et al. (2016) for the data collection. A group of experts and policy makers provided feedback on the user interface requirements, functional requirements, and end user requirements. This feedback process helped the research team identify key desired features of the app and their functionality. Based on the three indicating factors identified by Casey et al. (2016) (speed, distance and time) that define conflict severity, the app asks a set of survey questions. Question 3 asks a set of questions on the user-friendliness and is designed on a five point Likert scale. The first question (3a) asks the users whether the app use is intuitive or not. More than 65% of the participants *agree or strongly agree* that they can use the app intuitively and approximately 30% remained impartial. The second question (3b) asks whether the users can easily answer the app survey questions. These survey questions ask the users about who is reporting the conflict, the type of parties involved in the conflict, their speed, the separation distance and the time for taking any action. A combination of this information actually identifies a specific conflict scenario and its associated severity level. More than 78% of the participants *agree or strongly agree* that the app survey seems easy to complete and most of the remainder (20%) remain impartial. More than 70% of the participants *agree or strongly agree* that the map and symbols appear clear or easy to understand (question 3c) and the rest of them either disagreed or remained impartial. The next question (3d) asks the participants about how accurately they could determine the location of the conflicts received mixed feedback. Approximately, 22% of the participants express some difficulty in marking the location on the map. Interestingly, 68% of the participants who agree or strongly agree in the Likert type questions that the participants are able to accurately determine the location of conflicts, 14% of them also express difficulty in marking the location on the.

6.5.2. Inconsistencies and problems of the app.

While most of the participants say they do not see any problem with the app, some suggest otherwise. Approximately 17% of the participants say that they are not able to capture what they want and about 29% of them suggest inclusion of a customized incident reporting option as the app is unable to capture

other types of conflicts such as vehicle-vehicle conflicts. The collection of conflict data between vehicle and vehicle is intentionally left absent from the app because it remains beyond the scope of this research study; however, this does not preclude its future inclusion. Approximately 42% of the participants said they had issues with slower and crashing app while 12 % said that some features of the app did not work. The research team subsequently corrected the app crashing problem, which occurred for some older versions of the Android phone. The comments about the app features likely resulted from the experimental design, which prohibits some user groups from seeing conflicts recorded by others or receiving notifications. Furthermore, only admin users can download the database while the regular users cannot, but the interface appears the same for both. As some of the participants suggested that the sharing option or search option did not work, this strongly indicates that they did not have that privilege and. Only about 10% of the users said they do not want a product like this whereas approximately 15% of the students showed a higher level of learning skills gained from the app. These participants (who gained skills) explained the necessity of having a strong conflict database and autonomous data collection system.

6.5.3. Daily Notification and Alerts.

Out of the 41 participants that took part in the feedback survey, 36% of them received a daily reminder to report any incident, 19% of them received a daily reminder and alerts when an incident is reported and 43% of them did not receive any notifications. For those 36% who just received daily reminder, 60% or more of them said they *disagree or strongly disagree* that the reminder/notifications provided by the app encouraged him/her to use the app in a timely manner and approximately 33% of them had a neutral opinion. For those of the 19% who received reminders and alerts, 62.5% of them *disagreed or strongly disagreed*, 37.5% mentioned otherwise. While more than half of the participants (60.87%) disagree or strongly disagree that the notification encouraged them. Approximately 33% of the participants who mentioned about getting less notification (once every 1 hour instead of every 30 minutes), strongly agreed that the notification encouraged them. Some others suggest a customized option for notifications. Of those who received both notifications and alerts, 62% or more of them agree or strongly agree that the map showing incidents reported by other people is beneficial. More than 52% of the participants who said the point system encouraged them, also said the notification encouraged them. Among the participants (~61%) who may or will use the app in future, almost 76% said the point system encouraged them. 39% participants said they are not going to use the app again while the rest may or will use it again. Out of these 61% participants almost 32% said they will/very likely suggest the app to their friends, while 56% either remained impartial or less likely to suggest the app to a friend.

7. Conclusion and Future Recommendations

Merely considering crashes as the sole safety metric appears unsatisfactory, especially for bicyclists and pedestrians where any incident may likely result in an injury or fatality. As a result, near misses or conflicts need to be included in safety assessments for active modes especially in light of their potential chilling effect on participation in these modes. The project seeks to collect conflict information using an Android based app on specific pre-determined conflict evaluation questions identified by Casey et al. (2016). This data will help identify hot spots for conflicts and detailed analysis with crash locations can help find the failure mechanisms associated with these locations.

In response to the comments received from the field test participants, the team finalized the app with only two user groups. The regular or standard user group includes all app users who will be recording various conflict scenarios in their daily activity. Here, the users will receive a reminder once a day for recording any conflict they may have faced, and they also will receive prompt notification of any conflict recorded

by any other person in their zip code. This helps the users keep track of hot spot locations around their activity path. The second group of users includes those that will work with the data and represent 'admin' group of the app. These end users will use the data sharing option of the app to share the required database for any conflict analysis. The database can be shared as a *.CSV file or as a *.KML file, which can be opened in an Excel file or in a Google map file respectively. This will help perform hot spot analysis for researchers. The admins also have the option to add other users as an admin.

The initial field test of the app shows promise with support from many users in continuing to use the app and the app's effectiveness in mapping conflicts to previously recorded fatalities. Most of the field test users find the app easy to use and the survey questions easy to complete. The user concerns related to locating the conflict location accurately will need to be examined again in the future; however, at this time the researchers lack sufficient data because the research team appears to have failed in its marketing effort to generate sufficient excitement and interest in the app. Marketing efforts will need to be increased in the future to facilitate its broader adoption. After its broader adoption, the data quality and its linkage to crash rates will have to be reexamined. Furthermore, the field test failed to engage end users. Therefore, the usefulness of the data to end users will require further exploration in the future.

This study presents some significant opportunities for further research and development. Now that the concept has been proven, modifying the app to function on different platforms represents the most critical next step in the product development process. As such, the app will require further testing on a range of mobile devices (i.e., various models of Android, iPhone, Windows Phone). Future enhancements to the app may include giving access to various advocacy groups or running or biking groups to use their identity inside the app. This will help those groups customize the app according to their needs but also provide the essential data for end users. One possible enhancement may be the ability for an agency or advocacy group to respond to feedback emails from users in their jurisdiction or group. A detailed strategy on trying to snowball the app adoption among both end users and app users requires further development, and likely represents a research project exploring the role of social media/networks in the adoption of a crowd-source data collection instrument. As this project included the app as part of a class project, its use as a learning tool may be explored in more detail. Specifically, the future educational research should seek to assess the impact of the using the app on increasing the performance of students on learning outcomes related to bicycle and pedestrian safety and design.

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Appendix A: List of Stakeholders for Snowballing Process

Name	E-mail	Organizations	Title/Position
Kevin Kokes	kkokes@nctcog.org	NCTCOG: Bicycle and Pedestrian Programs, Plans/Trails (Regional)	Senior Transportation Planner
Daniel Snyder	dsnyder@nctcog.org	NCTCOG Bicycle and Pedestrian Advisory Committee (BPAC)	Transportation Planner I
Karla Weaver	kweaver@nctcog.org	NCTCOG Transportation Alternatives Program	Program Manager
Dan Lamers	dlamers@nctcog.org	NCTCOG	Program Manager
Trey Ingram	tingram@nctcog.org	NCTCOG	
Zachary Thompson	zachary.thompson@dallascounty.org	Dallas County Public Health --	Director-Dallas County Public Health
Christopher Perkins	Christopher.Perkins@dallascounty.org	DCPH -* referred by Zachary Thompson	Medical Director/Health Authority
Rose Mary Bennett	RMBennett@TarrantCounty.com	Tarrant County Public Health --	Supervisor--Arlington Public Health Center
Belinda Hampton	bghampton@TarrantCounty.com	Tarrant County Public Health	Health Planner
Sam Adamie	SAAdamie@TarrantCounty.com	TCPH: *recommended by Belinda	Environmental Specialists
David G. Jefferson	DGJefferson@TarrantCounty.com	TCPH: *recommended by Belinda	Environmental Health Manager
Candace J. Parker	CJParker@TarrantCounty.com	TCPH: *recommended by Belinda	Manager, Planning & Policy in Public Health
Kamilah Hasan	kamilah.hasan@dentoncounty.com	Denton County Public Health	
Julia Ryan	julia.ryan@fortworthtexas.org	City of Fort Worth	Senior Planner, Transportation Planning

Name	E-mail	Organizations	Title/Position
Ashley Haire, Ph.D. P.E.	ashley.haire@dallascityhall.com	City of Dallas	Bicycle Engineer
Jared White	jared.white@dallascityhall.com	City of Dallas	Bicycle Transportation Manager
Julie Anderson	julie.anderson@cityofdenton.com	City of Denton	Bike/Ped Coordinator
Keith Fisher	kfisher@cityofkeller.com	Keller	SRTS Coordinator
Kurt Schulte	kschulte@waltermoore.com	Private Consultants	consultant-refered by M Berry
Jeff Whitacre	jeff.whitacre@kimley-horn.com		consultant-refered by M Berry
Drew Brawner	dbrawner@kimley-horn.com		consultant-refered by M Berry
Kevin Martini	kevin.p.martini@wmich.edu	WMU Office of Sustainability	Nonmotorized transportation coordinator
Paul Selden	directorroadsafety@kalamazoobicycleclub.org	Kalamazoo Bicycle Club	Director of road safety
Andrew Hoodwin	ahoodwin@gmail.com	Plano Bicycle Association (PBA)	President
Teri Kaplan	Teri.Kaplan@txdot.gov	Traffic Safety Programs------ Safe Routes to School (SRTS)Program	TX State Bicycle and Pedestrian Coordinator
Bryan Armstrong	armstrongb@michigan.gov	Michigan Bike and Ped Coordinator	SRTS Coordinator-MI
Josh DeBruyn	DeBruynJ@michigan.gov	MI-Referred by Bryan Armstrong	MI Bike and Pedestrian Coordinator
Meg Thomas Ackerman	MTAckerman@michiganfitness.org	SRTS Director-MI	SRTS Program Director-MI
Robin Stallings	robin@biketexas.org	Bike Texas	Executive Director
Brenda Chuleewah	brenda@biketexas.org		SRTS Teacher Training Program Manager
Fernando Martinez	fernando@biketexas.org		SRTS Program Manager

Name	E-mail	Organizations	Title/Position
Arthur Wendel	dvq6@cdc.gov		Team Lead, Healthy Community Design Initiative
Jackie Epping	jge5@cdc.gov	Centers for Disease Control and Prevention (Contact Dr. Amy Eyler with any questions about the network: aeyler@wustl.edu)	Public Health Scientist
Michelle Snitgen	msnitgen@michiganfitness.org	Promoting Active Communities Program - Michigan Department of Community Health	Active Communities Coordinator
Sabrina McCarty	sabrina.mccarty@austintexas.gov	City of Austin, Public Health--Health Eating and Active Living Promotion	Public Health Educator II
Doug Ballew	doug.ballew@austintexas.gov	City of Austin, Public Health *recommended by Sabrina McCarty	Prof Health Educator and Bicycle
Kristin Rosenthal	krosenthal@safekids.org	National SAFE KIDS Campaign	Program Manager
Mark Plotz	mark@bikewalk.org	National Center for Bicycling & Walking	Senior Associate
Steve Clark	stevelci151@gmail.com	League of American Bicyclists	Community Program Specialist
Kristin Bennett	Kristin.Bennett@Milwaukee.gov	National Complete Streets Coalition--Smart Growth America--Expert Panel Members	Milwaukee Bicycle and Pedestrian Coordinator
Philip Pugliese	ppugliese@outdoorchattanooga.com	Expert Panel Member	Bicycle Coordinator--Tennesee
Michael Ronkin	michaelronkin@gmail.com	Expert Panel Member	Created Complete Streets Workshop

Appendix B-1: Definition of Conflict Analysis Factors for Non-overtaking Conflicts

Non-overtaking Conflict Type	Factors	
	Severity of Evasive Action	Separation Distance
Pedestrian – Vehicle	Pedestrian Actions (Four Rating Levels) (*1*): 1. Light: A change from a walk to stop **2.** Medium: A change from a walk to jog **3.** Heavy: A change into a sprint. This is likely combined with a change of course after the deceleration or acceleration **4.** Emergency: Take emergency action such as jumping out of the street and may be coupled with a fast, sporadic change of course	Three Rating Levels (*1*): **1.** Far: Greater than one car length (> 20 ft) is available **2.** Medium: Between half and one car length (10 ft to 20 ft) **3.** Short: Less than half car length (< 10 ft)
Bicyclist – Vehicle	Bicyclist Actions (Four Rating Levels): **1.** Light: A slight change in speed and no change in direction **2.** Medium: A normal stop or moderate change in speed and no change in direction **3.** Heavy: A hard stop or controlled change in direction **4.** Emergency: An abrupt, uncontrolled change in direction	Three Rating Levels: **1.** Far: Greater than one car length (> 20 ft) is available **2.** Medium: Between half and one car length (10 ft to 20 ft) **3.** Short: Less than half car length (< 10 ft)
Pedestrian – Bicyclist	Bicyclist Actions (Four Rating Levels): **1.** Light: Cruising away from pedestrian with a change of direction **2.** Medium: A moderate but controlled deceleration and likely combined with a change of direction **3.** Heavy: A sharp, less controlled deceleration and no change of direction **4.** Emergency: A sudden, uncontrolled deceleration or no change of direction Pedestrian Actions (Four Rating Levels): **1.** Light: A change from a walk to stop **2.** Medium: A change from a walk to jog **3.** Heavy: A change into a sprint. This is likely combined with a change of course after the deceleration or acceleration	Three Rating Levels: **1.** Far: Greater than one bicycle length (> 10 ft) is available **2.** Medium: Between half and one bicycle length (5 ft to 10 ft) **3.** Short: Less than half bicycle length (< 5 ft)

Non-overtaking Conflict Type	Factors	
	Severity of Evasive Action	Separation Distance
	4. Emergency: Take emergency action such as jumping out of the street and may be coupled with a fast, sporadic change of course	

Appendix B-2: Definition of Conflict Analysis Factors for Overtaking Conflicts

Overtaking Conflict Type	Factors	
	Lateral Distance	Speed
Vehicle – Bicyclist (Overtaking)	Two Rating Levels: **1.** Close: Lateral distance between vehicle and bicyclist is <= 3 ft **2.** Far: Lateral distance between vehicle and bicyclist is > 3 ft	Vehicle Speed (Four Rating Levels): **1.** Slow: <= 10 mph **2.** Average: 11 - 20 mph **3.** Moderate: 21 - 40 mph **4.** Fast: > 40 mph
Bicyclist – Pedestrian (Overtaking)	Two Rating Levels: **1.** Close: Lateral distance between pedestrian and bicyclist is <= 3 ft **2.** Far: Lateral distance between pedestrian and bicyclist is > 3 ft	Bicyclist Speed (Three Rating Levels): **1.** Slow: <= 10 mph **2.** Average: 11 - 20 mph **3.** Fast: > 20 mph

Appendix C-1: a. Severity of Conflict Categories, b. Non-overtaking vehicle-pedestrian conflict, c. Non-overtaking vehicle-bike conflict, d. Non-overtaking bike-pedestrian conflict, e. Abbreviated Safety Category

a

Conflict Category	Color Code
Category A is a serious incident in which a collision is narrowly avoided	
Category B is an incident with significant potential for a collision where separation decreases and incident may result in a time critical response to avoid a collision	
Category C is an incident characterized by moderate time and/or distance to avoid a collision	
Category D is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single vehicle/person	

b

Time	More					Sufficient					Barely				
Speed	Very Slow	Slow	Moderate	Fast	Very Fast	Very Slow	Slow	Moderate	Fast	Very Fast	Very Slow	Slow	Moderate	Fast	Very Fast
Pedestrian – Vehicle Conflict Analysis Factors	None	None	None	Light	Light	Light/Med	Light/Med	Medium	Heavy	Heavy	Heavy	Heavy	Emergency	Emergency	Emergency
Separation Distance Vehicle-Pedestrian, Far (> 20 ft)	D S	D S	D S	D S	D S	C MS	C MS	C MS	B/C MS	B/C MS	B/C MS	B/C MS	A/B NS	A/B NS	A/B NS
Separation Distance Vehicle-Pedestrian, Medium (10 - 20 ft)	D S	D S	D S	C MS	C MS	B NS	B NS	B NS	B NS	B NS	B NS	B NS	A NS	A NS	A NS
Separation Distance Vehicle-Pedestrian, Short (< 10 ft)	B/C MS	B/C MS	B/C MS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS

c

Time	More					Sufficient					Barely				
Speed	Very Slow	Slow	Moderate	Fast	Very Fast	Very Slow	Slow	Moderate	Fast	Very Fast	Very Slow	Slow	Moderate	Fast	Very Fast
Bicyclist – Vehicle Conflict Analysis Factors	None	None	None	Light	Light	Light/Med	Light/Med	Medium	Heavy	Heavy	Heavy	Heavy	Emergency	Emergency	Emergency
Separation Distance Vehicle-Bicyclist, Far (> 20ft)	D S	D S	D S	D S	D S	C MS	C MS	C MS	B NS	B NS	B NS	B NS	A NS	A NS	A NS
Separation Distance Vehicle-Bicyclist, Medium (10 - 20 ft)	D S	D S	D S	C MS	C MS	B NS	B NS	B NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS
Separation Distance Vehicle-Bicyclist, Short (< 10 ft)	B NS	B NS	B NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS	A NS

d

Time	More			Sufficient			Barely		
Speed	Slow	Moderate	Fast	Slow	Moderate	Fast	Slow	Moderate	Fast
Bicyclist - Pedestrian Conflict Analysis Factors	None	None	Light	Light/Med	Medium	Heavy	Heavy	Emrgcy	Emrgcy
Separation Distance Bicycle-Pedestrian, Far (> 10 ft)	D S	D S	D S	D MS/S	D MS/S	B/C MS	B/C MS	A NS	A NS
Separation Distance Bicycle-Pedestrian, Medium (5 - 10 ft)	D S	C MS	C MS	B NS	B NS	B NS	B NS	A NS	A NS
Separation Distance Bicycle-Pedestrian, Short (< 5 ft)	C MS	C MS	B NS	A NS	A NS	A NS	A NS	A NS	A NS

e

Short Form	Category
S	Safe
MS	Moderately Safe
NS	Not Safe

Appendix C-2: Severity of Overtaking Conflicts for different scenarios for a. Vehicle-bicyclist, b. Bicyclist-pedestrians

a

Vehicle – Bicyclist Overtaking Conflict Analysis Factors	Vehicle Speed, Very Slow (<= 10 mph)	Vehicle Speed, Slow(11-20 mph)	Vehicle Speed, Moderate (21-30 mph)	Vehicle Speed, Fast (31-40 mph)	Vehicle Speed, Very Fast (40+ mph)
Lateral Distance Vehicle - Bicyclist, Close (<= 3 ft)	C/D* Safe	B Moderately Safe	A Not Safe	*A Not Safe*	A Not Safe
Lateral Distance Vehicle - Bicyclist, Far (> 3 ft)	D Safe	D Safe	C Moderately Safe	*B Moderately Safe*	B Moderately Safe

b

Bicyclist – Pedestrian Overtaking Conflict Analysis Factors	Bicycle Speed, Slow (<= 10 mph)	Bicycle Speed, Average (11-20 mph)	Bicycle Speed, Fast (20+ mph)
Lateral Distance Bicycle - Pedestrian, Close (<= 3 ft)	D Moderately Safe	A Not Safe	A Not Safe
Lateral Distance Bicycle - Pedestrian, Far (> 3 ft)	D Safe	C Moderately Safe/Safe*	C Not Safe

Appendix D-1: App User Focus Group Presentation

1/7/2017

APP CROWDSOURCING TOOL FOR SAFE PEDESTRIAN AND BICYCLE ENVIRONMENT

(USER-FRIENDLINESS AND DAILY USE)

FOCUS GROUP

MARCH 2, 2016

UNIVERSITY OF TEXAS AT ARLINGTON

NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENT

PURPOSE

- To improve the quality of the bicyclist and pedestrian safety data available to local governments.
- Identify the safety issues encountered by pedestrians and bicyclists.
- Capture localized and context-sensitive information, such as the nature and types of vehicle conflicts bicyclists and pedestrians encounter, about dangerous road segments.

FOCUS GROUP PURPOSE



- DATA NEEDS
  - Basic information
  - Ideal information
- FEASIBILITY
  - Ability to capture information
  - Potential error

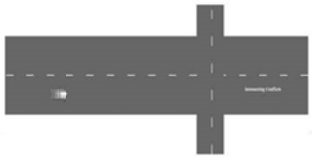
USER FLOWCHART

1

1/7/2017

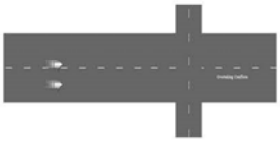
Q1. WHAT PARTIES ARE INVOLVED IN THE CONFLICT/RUN OVER/HIT SITUATON (INTERSECTING CONFLICT)?

a. Pedestrian and vehicle
b. Bicyclist and vehicle
c. Pedestrian and bicyclist



Q2. WHAT PARTIES ARE INVOLVED IN THE SIDE SWIPING SITUATION (OVERTAKING CONFLICT)?

- Bicyclist overtaking pedestrian
- Vehicle overtaking Bicyclist



(If 1.a. pedestrian-vehicle conflict was selected)
As a pedestrian, what was your/that person's evasive action? (What did you do?)

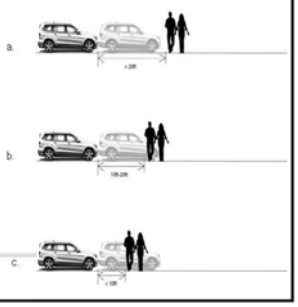
a. Walk to stop
b. Walk to jog
c. Walk to run



d. Walk to jump
e. Walk to sudden stop

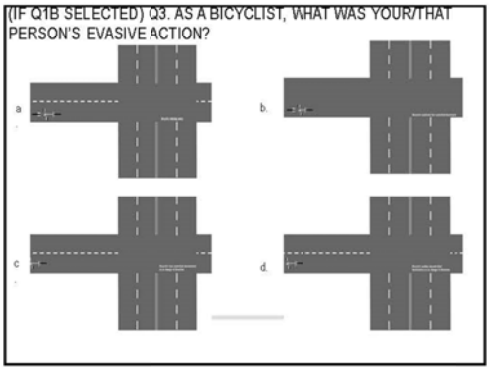


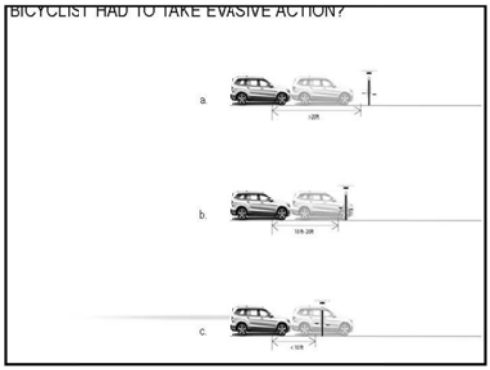
PEDESTRIAN HAD TO TAKE EVASIVE ACTION?

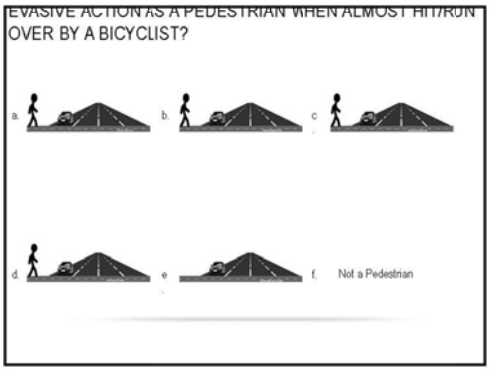


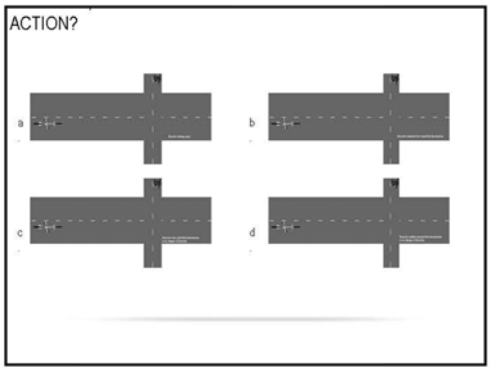
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1/7/2017


(IF Q1B SELECTED) Q3. AS A BICYCLIST, WHAT WAS YOUR/THAT PERSON'S EVASIVE ACTION?
a.
b.
c.
d.

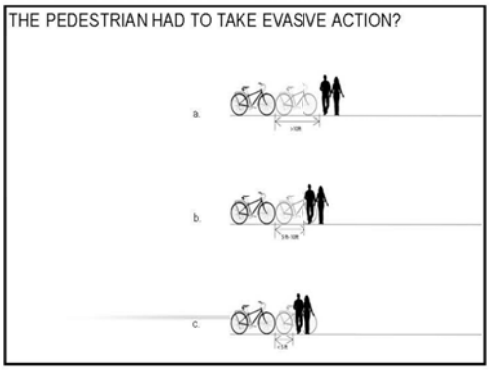

BICYCLIST HAD TO TAKE EVASIVE ACTION?
a.
b.
c.

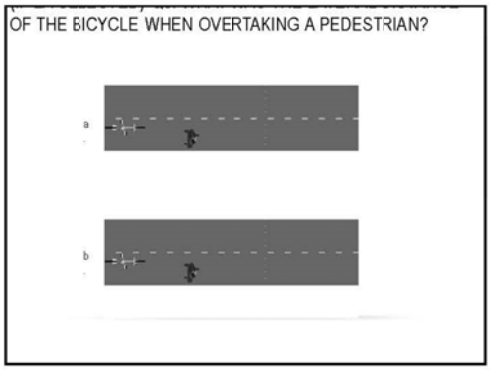

EVASIVE ACTION AS A PEDESTRIAN WHEN ALMOST HIT/RUN OVER BY A BICYCLIST?
a.
b.
c.
d.
e.
f. Not a Pedestrian

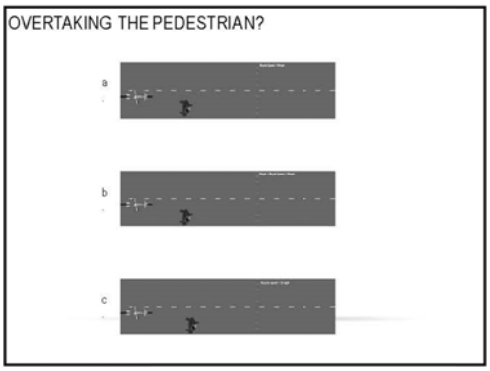

ACTION?
a
b
c
d

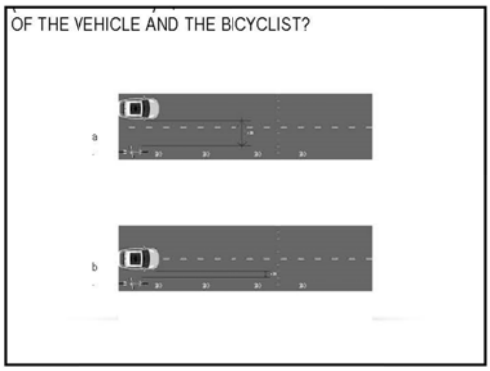
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1/7/2017


THE PEDESTRIAN HAD TO TAKE EVASIVE ACTION?
a.
b.
c.

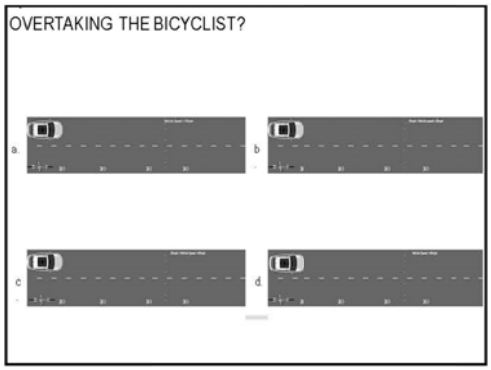

OF THE BICYCLE WHEN OVERTAKING A PEDESTRIAN?
a
b

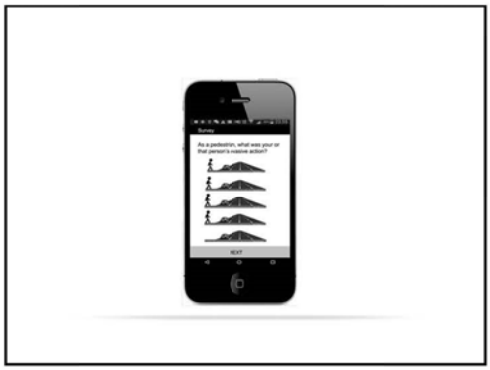

OVERTAKING THE PEDESTRIAN?
a
b
c

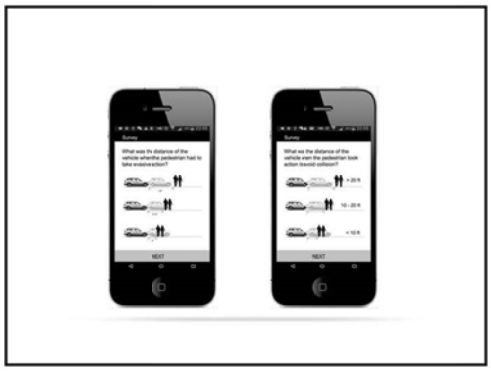

OF THE VEHICLE AND THE BICYCLIST?
a
b

4

1/7/2017







DISCUSSION ABOUT USER-FRIENDLINESS

5

1/7/2017

DISCUSSION ABOUT DAILY USE

THANK YOU

6

Appendix D-2: End User feedback survey presentation

1/7/2017

APP CROWDSOURCING TOOL FOR SAFE PEDESTRIAN AND BICYCLE ENVIRONMENT

(DATA NEEDS AND FEASIBILITY)

FOCUS GROUP

MARCH 3, 2016

UNIVERSITY OF TEXAS AT ARLINGTON

NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENT

PURPOSE

- To improve the quality of the bicyclist and pedestrian safety data available to local governments.
- Identify the safety issues encountered by pedestrians and bicyclists.
- Capture localized and context-sensitive information, such as the nature and types of vehicle conflicts bicyclists and pedestrians encounter, about dangerous road segments.

FOCUS GROUP PURPOSE



- DATA NEEDS
  - Basic informaion
  - Ideal informaton
- FEASIBILITY
  - Ability to capture information
  - Potential erro

USER FLOWCHART

1

1/7/2017

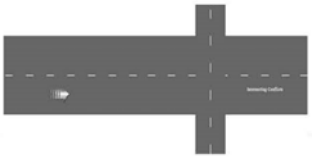
FOR ALL USERS:
Select Location



- Features
  - Select location of conflict
- Potential
  - Show previous conflicts (within an area)
  - Community sharing?

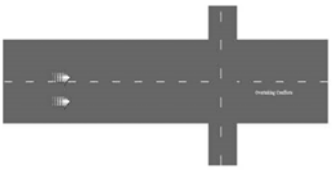
FOR ALL USERS:
Q1. What parties were involved in the conflict/run over/hit situation (intersecting conflict)?

a. Pedestrian and vehicle
b. Bicyclist and vehicle
c. Pedestrian and bicyclist



Q2. What parties were involved in the side swiping situation (overtaking conflict)?

a. Bicyclist overtaking pedestrian
b. Vehicle overtaking bicyclist



EXAMPLE FOR PEDESTRIAN-VEHICLE INTERSECTING CONFLICT
Q3. As a pedestrian, what was your/that person's evasive action?

a. Walk to stop
b. Walk to jog
c. Walk to run

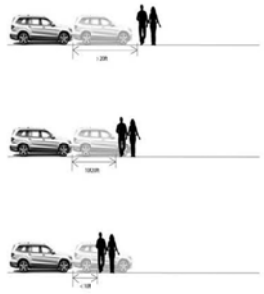


d. Walk to jump
e. Walk to sudden stop

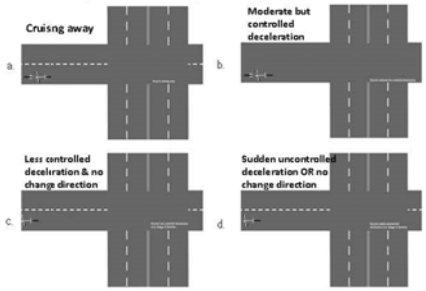


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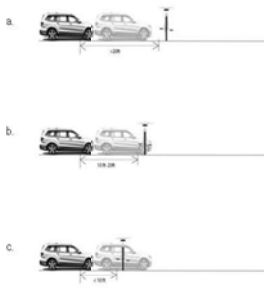
Q4. What was the distance of the vehicle when the pedestrian had to take evasive action?



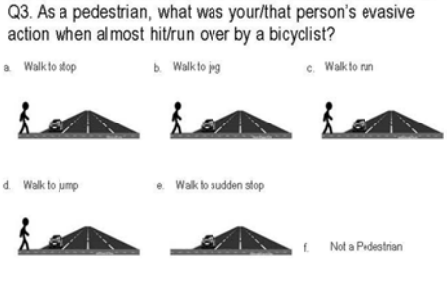
EXAMPLE FOR BICYCLE-VEHICLE INTERSECTING CONFLICT
Q3. As a bicyclist, what was your/that person's evasive action?



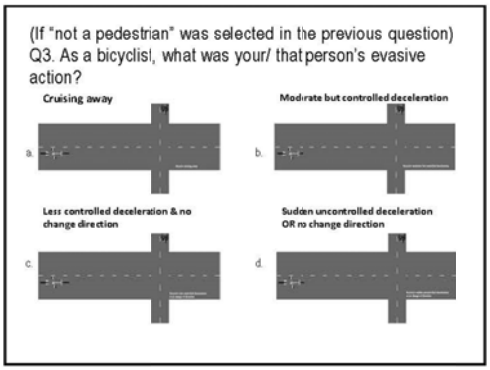
Q4. What was the distance of the vehicle when the bicyclist had to take evasive action?

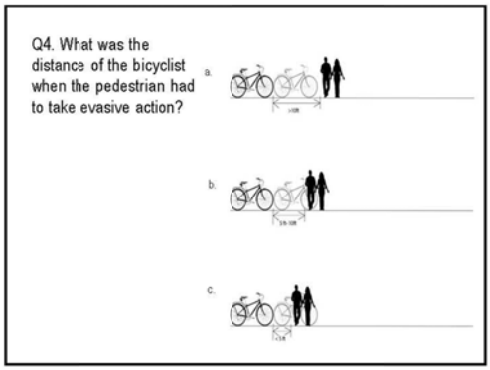


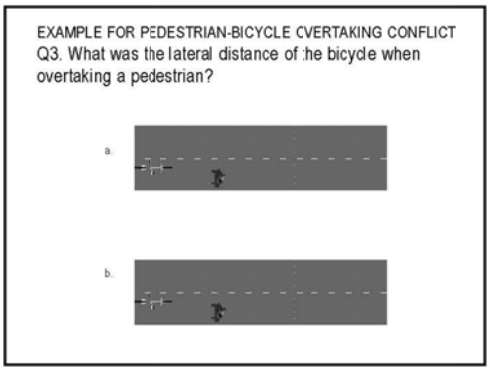
EXAMPLE FOR PEDESTRIAN-BICYCLE INTERSECTING CONFLICT
Q3. As a pedestrian, what was your/that person's evasive action when almost hit/run over by a bicyclist?

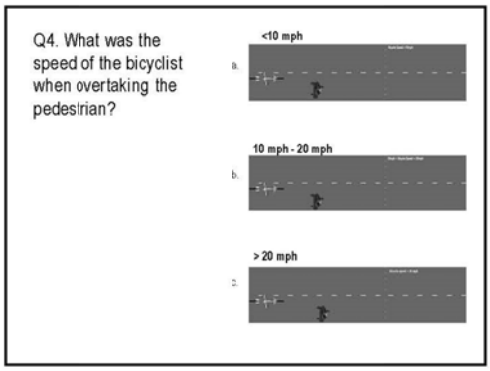


1/7/2017


(If "not a pedestrian" was selected in the previous question)
Q3. As a bicyclist, what was your/ that person's evasive action?
Cruising away
Moderate but controlled deceleration
Less controlled deceleration & no change direction
Sudden uncontrolled deceleration OR no change direction


Q4. What was the distance of the bicyclist when the pedestrian had to take evasive action?


EXAMPLE FOR PEDESTRIAN-BICYCLE OVERTAKING CONFLICT
Q3. What was the lateral distance of the bicycle when overtaking a pedestrian?


Q4. What was the speed of the bicyclist when overtaking the pedestrian?
<10 mph
10 mph - 20 mph
> 20 mph

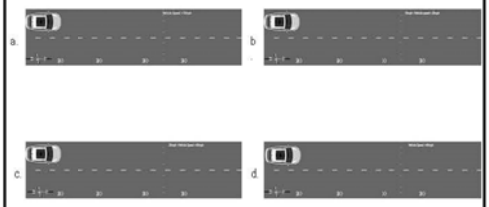
4

1/7/2017

EXAMPLE FOR BICYCLE-VEHICLE OVERTAKING CONFLICT
Q3. What was the lateral distance of the vehicle and the bicyclist?



Q4. What was the speed of the vehicle while overtaking the bicyclist?

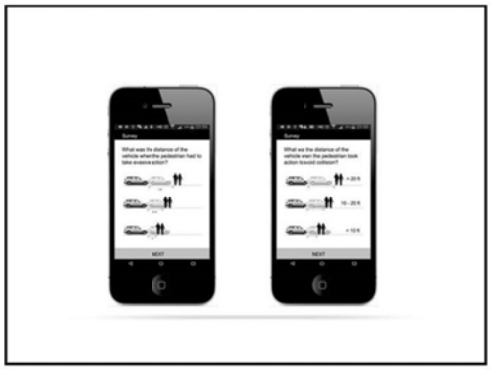


Q5. What was the severity of the conflict?





5



DISCUSSION ABOUT DATA NEEDS

DISCUSSION ABOUT FEASIBILITY

THANK YOU

Appendix E: Data Dictionary (Q63-69 and Q73-79 from flow chart (Figure 2) are repetition of Q61-62 and Q71-72 for other combination of scenarios)

Variables	Definition/ Question	Examples/Answers
useremail	The original email address of users that he/she use in google play store account	abcd@gmail.com
conflictdatetime	**Time** of conlficts; **Date** format: Year-MM-DD and Time format: HH:MM:SS.00;	2016-06-08T15:25:00.000Z
latitude	**Latitude** of incident	32.73154419
longitude	**Longitude** of incident	-97.11443905
StreetAdreess	Address	416 Yates street, arlington, TX 76019
IncidentZipcode	**Zipcode** of the **incident** location	76019
Q1	Did you experience a conflict?	a: Yes; b: No
Q2	Was it a collision or a conflict?	a: An actual hit/crash/collision; b: A conflict/near miss
Q3	In case of no conflict recorded (Q1=b), What type of **activity** did you do today?	a: Walk/Run; b: Bike; c: None
Q41	In case of collision (Q2=a), What type of **activity** did you do today?	a: Walk/Run; b: Bike; c: None
Q42	Please identify your **injury level**.	a: Major Injury (Disabling); b: Minor Injury (non-disabling); c: Minimal Injury (Possible abrasions and bruises); d: No Injruy (property Damage only)
Q43	Were you transported to **hospital by an ambulance**?	a: Yes; b: No
Q44	Did you got admitted to a hospital?	a: Yes; b: No
Q51	Who were **involved**?	a: Pedestrian and vehicle; b: Bicyclist and vehicle; c: Pedestrian and bicyclist
Q52	Who is reporting?	a: Bicyclist; b: Pedestrian
Q53	Were both parties traveling in the same direction?	a: Yes; b: No
Q61	**Vehicle Speed**: when traveling past a pedestrian/bicyclist	a: Very slow (<=10 mph); b: Slow (10-20 mph); c: Moderate (20-30 mph); d: Fast (30-40 mph); e: Very fast (>40 mph)
Q62	**Bicyclist Speed**: when traveling past a pedestrian	a: Slow (<=10mph); b: Moderate (10-20 mph); c: Fast (>20 mph)
Q71	**Distance of the Vehicle**: from a pedestrian/bicyclist	a: Greater than one car length (>20ft); b: Between half and one car length (10-20ft); c: Less than half car length (<10 ft)
Q72	Distance of the Bicyclist: from a pedestrian	a: Greater than one bike length (<10 ft); b: between half and one bike length (5-10 ft); c: less than half a bike length (<5ft)

Q73	**Lateral Distance** (if Q53=a): between vehicle and bicyclist or between pedestrian and bicyclist	a: Less than 3ft; b: Greater than 3ft
Q8	(for all Q6 and Q7 except Q53-a) **How much time** did you have to take safety measure to avoid a crash?	a: More than enough time, able to think about and select from a variety of safe actions; b: Sufficient time, but made quick decision and acted; c: Barely enough time, only quick reactions avoided a crash
Severity of Conflicts	**Severity categories of conflict** based on the options selected in Q1-8; Severity is present in Red, Orange, yellow and Green color	**Category A** is a serious incident in which a collision is narrowly avoided **Category B** is an incident with significant potential for a collision where separation decreases and incident may result in a time critical response to avoid a collision. **Category C** is an incident characterized by moderate time and/or distance to avoid a collision. **Category D** is an incident with no immediate safety conseqences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single vehicle/person
Q91	What was the purpose of your trip?	a: Home-work-home trip; b: leisure/exercise; c: family errands; d: other, user specified
Q92	What was the **road condition**?	a: Dry; b: Wait; c: Other, user specified
Q93	Additional Comments	User comment box
Q94	Participants **home zipcode**	76010

Appendix F: Conflict Analysis Manual

Conflict Analysis

Introduction

Pedestrians' exposure to the risk of conflicts with vehicles, bicycles, or other pedestrians is very difficult to assess, since it requires tracking the movement of all involved parties in real-time. However, conflicts with transportation infrastructure can be somewhat measured. Vision based studies related to pedestrians and bicycles have shown increasing potential (*1-8*). Traditionally, collision or crash data play a key role in modelling the pedestrian or bicycle injury risk as a function of transportation characteristics and other factors. Pedestrian safety analysis using non-collision data mostly rely on traffic conflicting analysis (*9-17*). Motorist yielding rate (with respect to pedestrians) is also mentioned in the literature (*18*).

Initially, quantitative methods based on road user response to conflicts are proposed. Then, gradually conflicting analysis become more quantitative (*19-27*). The U.S Department of Transportation Conflict Technique (USDTCT) from Federal Highway Admiration (FHWA) categorize various elements that induce conflicts; create the level of severity by each element; sum the severity levels of each element and finds the overall grade of the severity of the conflict (*22*). Like USDTCT, the Swedish Traffic Conflicts Technique (STCT) (*20*), and the Institute of Highways and Transportation Conflicts Technique (IHTCT) (*21*) were developed for vehicle to vehicle conflict analysis. However, these techniques were used for vehicle-pedestrian conflict analysis. For instance, modelling interaction between left-turning vehicles and pedestrians at signalized intersections (*28*), assessing the efficiency of safety regulations for vulnerable road users at intersections (*29*), and qualitative categorization of conflict types and severity (*30*) are some cross applications of vehicle-vehicle conflict based methods. Also, a modified version of IHTCT method is used to develop vehicle-pedestrian conflict analysis method (*31*).

Vehicle-Pedestrian Conflicts

During vehicle-pedestrian conflicts both vehicle's and pedestrian's interaction shall be accounted. In general, pedestrians are subjected to less restrictions (compare to maneuverability and operations of vehicles facing conflicting situations) and more responsive and flexible while taking evasive actions. Compare to pedestrians, vehicular traffic feels little freedom in taking actions when conflicted with pedestrians. Few research studies developed vehicle-pedestrian conflict methodology using vehicle-vehicle conflict based methods. The research team adopted a vehicle-pedestrian conflicting technique developed by *Kaparias et. al.* (2010) with some modifications. The method proposed by *Kaparias et. al.* qualitatively assesses conflict severity grade using video based pedestrian data. The qualitative nature of the assessment, board applicability, ease of assessment, and relatively less data intensive nature helps the research team to adopt *Kaparias et. al.* methodology.

Kaparias et. al. developed vehicle-pedestrian conflicting technique based on vehicle–vehicle conflict analysis techniques. This technique is based on Institute of Highways and Transportation Conflict Technique (IHTCT) developed by Transport and Road Research Laboratory. In the above method, a conflict is defined as being "an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged". Four factors: time to collision, severity of evasive action, complexity of evasive action, and distance to collision were considered important in analyzing conflicts. Each factor has more than one severity rating levels to classify conflicts. The severity rating level to each of four factors are accounted to determine an overall grade category for the conflict. Conflict categories range from A to D, with Grade 1 conflicts being characterized "slight" and Grade 2, 3, and 4 conflicts corresponding to "serious" conflicts with increasing severity.

Methodology

In the present method, a conflict is defined as "an observational situation in which a vehicle and pedestrian approach or encroach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged" (*31*). Three factors: *speed of the approaching vehicle, separation distance between vehicle and pedestrian* and *time to take an action* are considered important in analyzing conflicts. Each factor has more than one rating level to classify conflicts. The rating levels for each factor are added to determine an overall grade category for a conflict. Conflict categories range from A to D, with category A conflicts being characterized "serious" and category B, C, and D conflicts corresponding to conflicts with decreasing severity. The following section presents a brief overview of each factor and its severity rating classifications.

Factors in Analyzing Vehicle – Pedestrian Conflicts

1. Speed of the approaching vehicle:

   Vehicles when approaching a pedestrian at the intersection can be at different speed based on the speed limit of the road or braking. Pedestrian's hierarchy of severity of evasive actions follows as above. The different levels of speed of approaching vehicle considered here are:

   a. Very Slow (<=10 mph)
   b. Slow (11-20mph)
   c. Moderate (21-30mph)
   d. Fast (31-40mph)
   e. Very Fast (40+mph)

2. Separation Distance between Vehicle and Pedestrian (*31*):

   a. Far

      Greater than one car lengths (>20 ft) between the conflicting road users

when they begin to take an action to avoid the collision.

b. Medium
Between half and one car lengths (10 ft to 20 ft) between the conflicting road users when they begin to take action to avoid the collision.

c. Short
Less than half a car length (<10 ft) between the conflicting road users when they begin to take action to avoid the collision.

3. Time left to take safety measure to avoid a crash
   a. More than enough time, able to think about and select from a variety of safe actions.
   b. Sufficient time, but made quick decision and acted
   c. Barely enough time, only quick reactions avoided a crash

Categories of Conflicts

There are four categories of conflicts (*32*):

- Category A is a serious incident in which a collision is narrowly avoided.
- Category B is an incident with significant potential for collision where separation decreases and incident may result in a time critical response to avoid a collision.
- Category C is an incident characterized by moderate time and/or distance to avoid a collision.
- Category D is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single vehicle/person.

Survey Data Collection

Conflict data between vehicles and pedestrians are collected using "Safe Activity". The data collection covers both intersection and street segments. Vehicular turning movements (either left turns or right turns) are potential conflicts with the pedestrians crossing an intersection. Mid-block or driveway crossings cause conflicts on street segments.

Survey Locations

Though project primarily concentrates data collection at school locations, other potential locations where significant vehicle and pedestrian conflicts occur may also be considered. Situations where either vehicle or pedestrian are hypersensitive in avoiding collisions, or yield to each other courteously may not constitute a conflict. Thus, survey team may avoid those situations. Survey should be collected when both pedestrian and vehicles activities are predominant (for instance, morning or afternoon peak period of elementary schools or evening school closing times are better for data collection at school locations). Also, adverse weather conditions affect pedestrian activities, avoid surveying on those days.

Calculation of a Conflict Category

Once an observer identifies a conflict situation, the appropriate response are identified by user in the android app. The app database then identifies the conflict category defined by the developers and interactive GIS map shows the severity level in google map. If multiple vehicles and pedestrians are involved at a given conflict situation, treat vehicle group as one vehicle where worst conflict grade among all involved vehicles will prevail. Similarly, worst pedestrian conflict grade among all involved pedestrians yield pedestrian conflict grade.

Bike Related Conflict Analysis

According to Pulugurtha *et al.* (2008), "Adequate daily physical activities are important to a healthy life. However, studies have shown that the proportion of walk trips and bike trips in the United States decrease from 6.7% to 4.4% over a decade during the 1990s. The decrease in physical activity in governed by several aspects, including safety, absence of safe facilities to walk or bicycle, congestion and air quality, jobs-housing location imbalance, longer commuting times, diminishing open space and agricultural lands, absence of community life, urbanization, and growth and the development of the environment. Aside from these aspects, residents of suburban developments often depend on their automobiles for trips to destinations within the neighborhood because of circuitous street layouts, long travel distances, lack of pedestrian safety, and lack of pedestrian facilities such as sidewalks, pedestrian crosswalks, signs, and pedestrian signals. Building neighborhoods that provide safe pedestrian and bicycling environments, more green space, network connectivity, and access to transit system will help address the growing problems related to pedestrian and bicycling safety, physical activity, and congestion."

According to National Highway Traffic Safety Administration (NHTSA), in 2012, 4743 pedestrians and 726 bicyclists were killed by motor vehicle accidents which are respectively only 6.24 percent and 1.48 percent of total pedestrian and bicycle injury. Only 12 percent of total injury of pedestrians and 29 percent of total injury of bicyclists are caused by motor vehicles [3]. Tuckel (2009) showed that, more than 1000 pedestrians' accidents occurred by cyclists. But this number does not cover those who visit their doctor's office or walk-in clinic [1].

California Vehicle Code Awareness stated that inattention, passing, turning, freeway egress, driving under the influence and motor vehicle design are some of the most important causes of bicyclists and vehicle conflicts [2].

Motorists often failed to yield to pedestrians in marked multilane crosswalks at uncontrolled locations. Pedestrian have a significant influence on vehicle capacities of turning movements at signalized intersections. The increasing emphasis on pedestrians' traffic has highlighted deficiencies in the relevant research in china. It is imperative to quantify accurately the effect of pedestrians on vehicle capacity to provide a basis for traffic operations and facility designs in mixed traffic condition.

A conflict zone is a portion of an intersection, typically in the crosswalk, in which pedestrians and vehicles compete for space. Complex interactions occur between the competing pedestrians and vehicles at conflict zones in intersections. Although pedestrians-vehicle conflicts can be avoided by time separation control, all the conflicts usually cannot be eliminated in consideration of traffic efficiency. Common conflicts between pedestrians and right turns are shown. The conflict zones are usually the bottlenecks of the right-turning movements therefore, the traffic conditions and conflict mechanisms serve as the basis for capacity calculation [12].

Vehicle- Bike Conflicts

In case of vehicle and bike, conflict does not only occur at the intersection but they also occur because of lateral movement. Due to shared bike lane with vehicle, overtaking maneuver needs to be analyzed properly. For Intersection, the same data collection procedure and calculation of conflict category will be followed as stated before in vehicle-pedestrian conflict analysis. When vehicles and bicyclist are moving in a shared lane, often vehicle need to overtake the bike and conflict may occur in these cases. Based on literature review, it is important that every vehicle leave at least 3 ft gap while crossing a bicycle. At the same time, the speed of the passing vehicle is also important for accessing the severity of plausible conflict.

Bike-Pedestrian Conflicts

In a mixed path trail, bicyclist can pose serious problem to pedestrians. Both non-overtaking and overtaking conflict may occur in these scenarios.

Non-overtaking Methodology

Separation distance between vehicle and bicyclist and between bicyclist and pedestrians, the speed of the crossing vehicle or bicyclist and the time to take an action are considered important in analyzing conflicts. Each factor has more than one rating level to classify conflicts. The rating levels for each factor are added to determine an overall grade category for a conflict. Conflict categories range from A to D, with category A conflicts being characterized "serious" and category B, C, and D conflicts corresponding to conflicts with decreasing severity. The following section presents a brief overview of each factor and its severity rating classifications.

Factors in Analyzing Vehicle – Bicyclist Conflicts

The different levels of speed of approaching vehicle considered here are:

a. Very Slow (<=10 mph)
b. Slow (11-20mph)
c. Moderate (21-30mph)
d. Fast (31-40mph)
e. Very Fast (40+mph)

4. Separation Distance between Vehicle and bicyclist (*31*):
   a. Far
      Greater than one car lengths (>20 ft) between the conflicting road users

when they begin to take an action to avoid the collision.

b. Medium

Between half and one car lengths (10 ft to 20 ft) between the conflicting road users when they begin to take action to avoid the collision.

c. Short

Less than half a car length (<10 ft) between the conflicting road users when they begin to take action to avoid the collision.

5. Time left to take safety measure to avoid a crash
   a. More than enough time, able to think about and select from a variety of safe actions.
   b. Sufficient time, but made quick decision and acted
   c. Barely enough time, only quick reactions avoided a crash

Categories of Conflicts

There are four categories of conflicts (*32*):

- Category A is a serious incident in which a collision is narrowly avoided.
- Category B is an incident with significant potential for collision where separation decreases and incident may result in a time critical response to avoid a collision.
- Category C is an incident characterized by moderate time and/or distance to avoid a collision.
- Category D is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single vehicle/bicyclist.

Factors in Analyzing Bicyclist– Pedestrian Conflicts

6. The different level of bicyclist speed considered in bicyclist-pedestrian conflict analysis are
   a. Slow (<=10mph)
   b. Moderate (11-20mph)
   c. Fast (20>mph)

7. Separation Distance between bicyclist and pedestrian:
   a. Far: Greater than one bike lengths (>10 ft)
   b. Medium: Between half and one bike lengths (5 ft to 10 ft)
   c. Short: Less than half a bike length (<5 ft)

8. Time left to take safety measure to avoid a crash
   a. More than enough time, able to think about and select from a variety of safe actions.
   b. Sufficient time, but made quick decision and acted
   c. Barely enough time, only quick reactions avoided a crash

Categories of Conflicts

There are four categories of conflicts (*32*):

- Category A is a serious incident in which a collision is narrowly avoided.

- Category B is an incident with significant potential for collision where separation decreases and incident may result in a time critical response to avoid a collision.
- Category C is an incident characterized by moderate time and/or distance to avoid a collision.
- Category D is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single bicyclist/person.

Overtaking Methodology

When vehicles overtake bicyclist or when bicyclist overtake pedestrian in a shared environment, conflicts occur in a different way and hence the data collection procedure, definition and categorization changes. In terms of overtaking, the lateral distance between the two parallel conflict zones and the speed while overtaking play important role. The following picture shows the flow chart in analyzing bicyclist-pedestrian overtaking conflict.

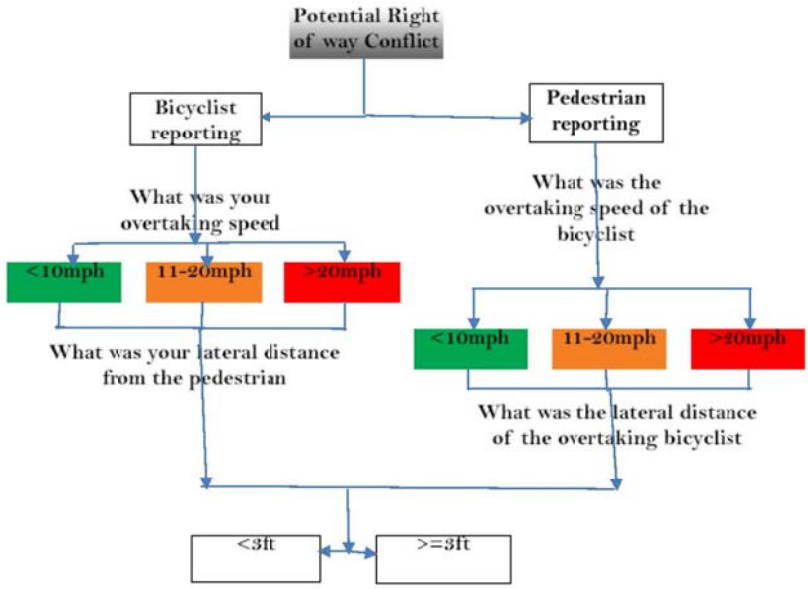


Figure 1 Flow Chart for Bicyclist-Pedestrian Conflict Analysis (Overtaking)

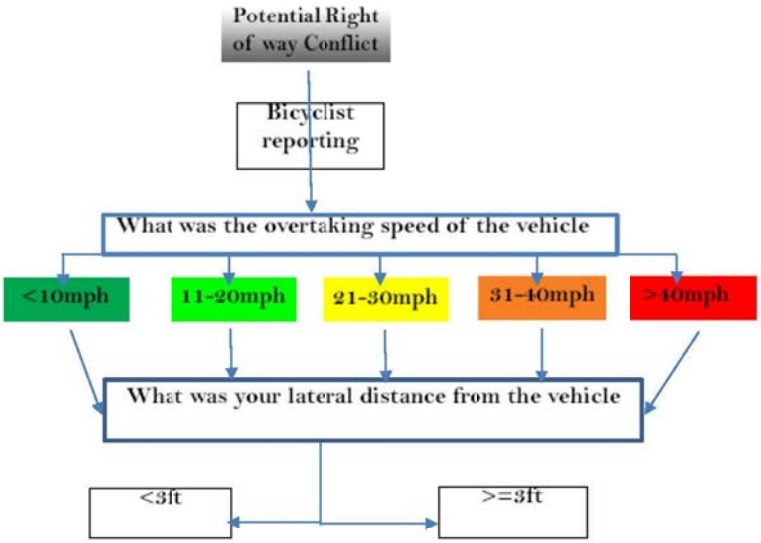


Figure 2 Flow Chart vehicle-bicyclist Conflict during Overtaking

Categories of Conflicts

There are four categories of conflicts (*32*):

- Category A is a serious incident in which a collision is narrowly avoided.
- Category B is an incident with significant potential for collision where separation decreases and incident may result in a time critical response to avoid a collision.
- Category C is an incident characterized by moderate time and/or distance to avoid a collision.
- Category D is an incident with no immediate safety consequences but met the definition of a conflict such as encroachment of the space/area of a roadway surface designated for a single bicyclist/person.

Table 1 Categories of Conflicts

Conflict Category	Lateral Distance	Speed of Passing vehicle/bike
Category A	Close	Fast
Category B	Close	Moderate

Conflict Category	Lateral Distance	Speed of Passing vehicle/bike
Category C	Close	Average
	Far	Average
Category D	Far	Average
	Far	Slow

Survey Data Collection

Use the app to record all types of overtaking conflict data during your recreational or utilitarian activity.

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Appendix G-1: App user feedback survey

Welcome

Thank you for your willingness to participate in field testing the safety app. The purpose of the study is to improve the quality of the data available to local governments by developing an crowdsourcing app for improving bicyclist and pedestrian safety. Most local governments and agencies rely on data after a crash. The use of an app can capture the nature and types of conflicts that bicyclists and pedestrians encounter on dangerous sites. If you have any questions, or would like to see the results of the analysis, please contact Dr. Colleen Casey at colleenc@uta.edu.

Your response will remain anonymous. There are no perceived risks as well as direct benefits to you as a participant in this study. Participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue participation at any time without penalty or loss of benefits. By clicking "NEXT" below, you confirm that you are 18 years of age or older and have read or had this document read to you. You have been informed about this study's purpose, procedures, possible benefits and risks, and you may print a copy of this form using the "Print" function in your browser. You have been given the opportunity to ask questions before you make a decision regarding your participation, and you have been told that you can ask other questions at any time. By clicking "NEXT" below, you are not waiving any of your legal rights. If you have questions about your rights as a research subjects, you may contact UTA Regulatory Services at regulatoryservices@uta.edu or call 817-272-3723.

1. What type of notification did you receive?

- ◯ Daily reminder to report incident
- ◯ Daily reminder to report incident and alerts when an incident is recorded
- ◯ None

2. Currently, each user gets a notifcation of incident(s) reported every 30 minutes. Please select your preference to improve this.

- ☐ More notifications (please specify the range in minutes below)
- ☐ Less notifications (please specify the range in minutes below)

Please specify

3. User-friendliness and interface

	1 (Stongly Disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly Agree)
I was able to use the app intuitively	☐	☐	☐	☐	☐
I can answer the questions easily	☐	☐	☐	☐	☐
The map and symbols are clear and easily understood	☐	☐	☐	☐	☐
I was able to accurately determine the location of conflicts	☐	☐	☐	☐	☐
The map shows the incidents (conflicts with other road users) that I reported	☐	☐	☐	☐	☐
The map shows incidents (conflicts with other road users) reported by other people	☐	☐	☐	☐	☐

4. What type of error/inconsistencies did you notice?

- ☐ It was difficult to mark location on the map
- ☐ The app did not record location on map accurately
- ☐ My phone seemed slower or had stopped more than once
- ☐ Some features of the app that did not work

Other (please specify)

5. The notifications that was provided via the app encouraged me to use the app in timely manner?

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

6. How likely will you use the app in the future?

- ◯ Will not use again
- ◯ May use again
- ◯ Will use again

Other (please specify)

7. Do the points encourage you to continue using the app?

- ◯ Yes
- ◯ No

* 8. How likely will you suggest the app to your friends?

- ◯ Very likely
- ◯ Don't know
- ◯ Less likely

9. If you are not likely to use the app, why not?

- [ ] The app is less useful because the information I want to provide cannot be captured by the app
- [ ] The app is not useful because it does not work properly
- [ ] It was difficult to remember information about previous conflicts with other road users
- [ ] I do not want a product like this
- [ ] I would like more features (please explain below)

Please specify your reasons:

10. Do you have suggestions on how to improve the app?

11. Please enter your name

Thank You!

Appendix G-2: End user feedback survey

Welcome

Thank you for your willingness to participate in our survey. The purpose of the study is to improve the quality of the data available to local governments by developing an crowdsourcing app for improving bicyclist and pedestrian safety. Most local governments and agencies rely on data after a crash. The use of an app can capture the nature and types of conflicts that bicyclists and pedestrians encounter on dangerous sites. If you have any questions, or would like to see the results of the analysis, please contact Dr. Colleen Casey at colleenc@uta.edu.

Your response will remain anonymous. There are no perceived risks as well as direct benefits to you as a participant in this study. Participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled, and you may discontinue participation at any time without penalty or loss of benefits. By clicking "NEXT" below, you confirm that you are 18 years of age or older and have read or had this document read to you. You have been informed about this study's purpose, procedures, possible benefits and risks, and you may print a copy of this form using the "Print" function in your browser. You have been given the opportunity to ask questions before you make a decision regarding your participation, and you have been told that you can ask other questions at any time. By clicking "NEXT" below, you are not waiving any of your legal rights. If you have questions about your rights as a research subjects, you may contact UTA Regulatory Services at regulatoryservices@uta.edu or call 817-272-3723.

1. What is your occupation?

2. What is the timeline of data availability that would help you most in performing your work?

- ◯ 1 - 5 years
- ◯ More than 5 years - 10 years
- ◯ More than 10 years (please specify)

Please specify

3. Safe Activity allows you to gain reported conflict incidents based on Zip codes and distance radius. What would be the scope of analysis most beneficial for your need?

- [ ] I can work with the existing options (Zip codes and distance radius)
- [ ] City boundaries
- [ ] County boundaries
- [ ] Census Block Groups or Tracts

Other (please specfy)

4. The different speed range categories used in the app conveyed the actual condition accurately

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree

5. The data dictionary is adequate enough for explaining the database

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree
- ◯ Other (please specify)

6. Sharing incident records with other stakeholders is convenient with the provided options in the app

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neutral
- ◯ Agree
- ◯ Strongly Agree
- ◯ Other (please specify)

7. Select the types of data that you would like to have the ability to download:

- ☐ compatible with web-based map system such as Google Maps
- ☐ compatible with GIS software

Other (please specfy)

8. Select the locations of conflicts that you are mostly concerned with in your work:

- ◯ Road segments
- ◯ Intersections
- ◯ Both
- ◯ Other (please specify)

9. Do you have concerns regarding the types of data from the app?

10. Do you have suggestions on how to improve the app?

Thank You!

Appendix H: Data download and analysis Example

Researchers, planners and policymakers can easily download the conflict data from the app into a *.kml format or in a *.csv format and perform desired analysis for a particular area of interest. The research team has developed an example scenario for end users, which is explained in detail in the following section.

Mr. John Doe is working for a XYZ Engineering Company and trying to do a conflict analysis for the City of Arlington. At the initial stage, Mr. Doe wants to find out the total number of conflicts along with their severity for a specific zip code. This will help him narrow down the area in the city and later a more specific smaller area such as census block (square are or polygon) can be considered for analysis.

Conflict selection by Zip code

An initial investigation of the conflict database suggests that more conflicts occur in zip code 76010. The steps the end users need to follow to gather all the conflicts that occur in 76010 are given below-

a. Collect a boundary map jpeg file for the specific zip code from the City of Arlington website

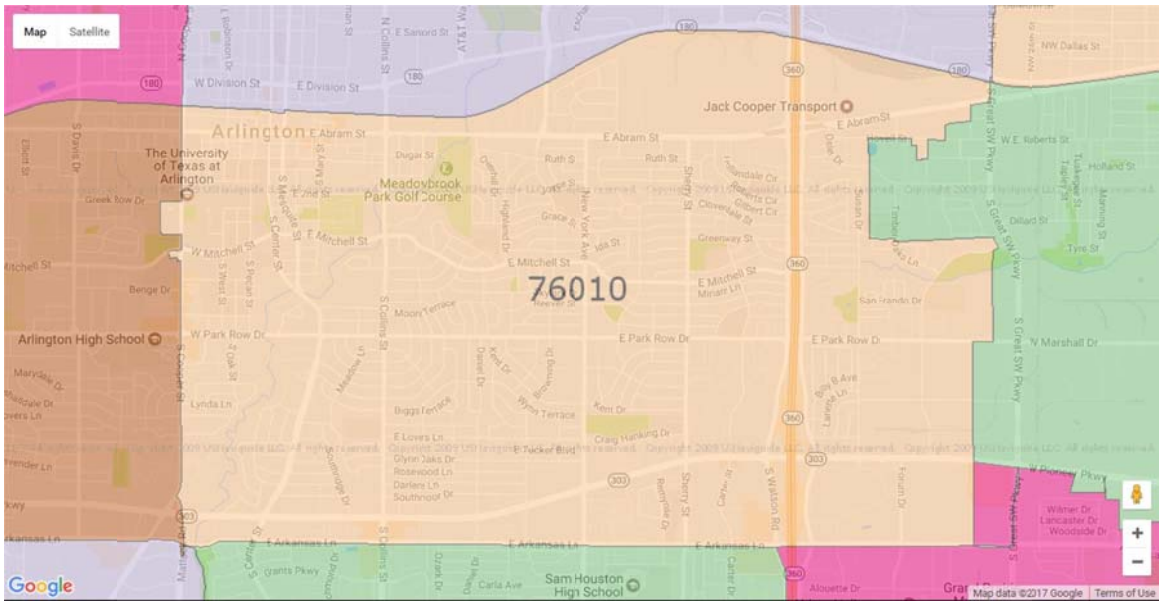


Figure H.1: Geographic map of zip code boundary area for 76010

b. Go to **Add** and select **Image Overlay**

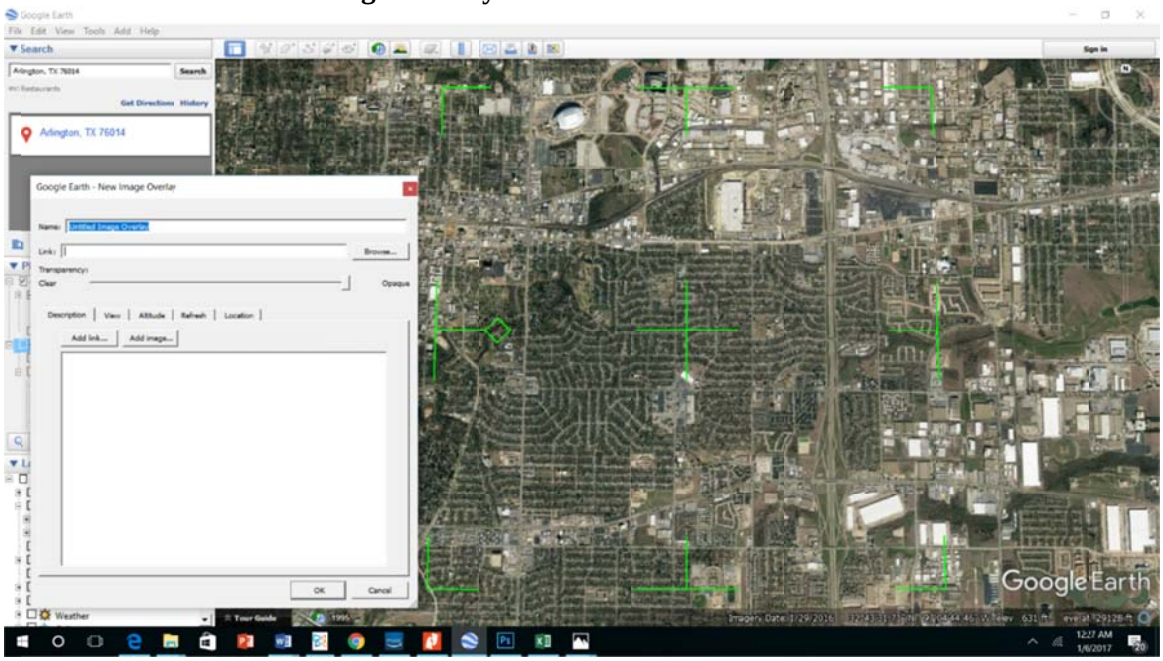


Figure H.2: Adding Image overlay in Google Earth

c. In the **New Image Overlay** window, select Browse and open the zip code jpeg file

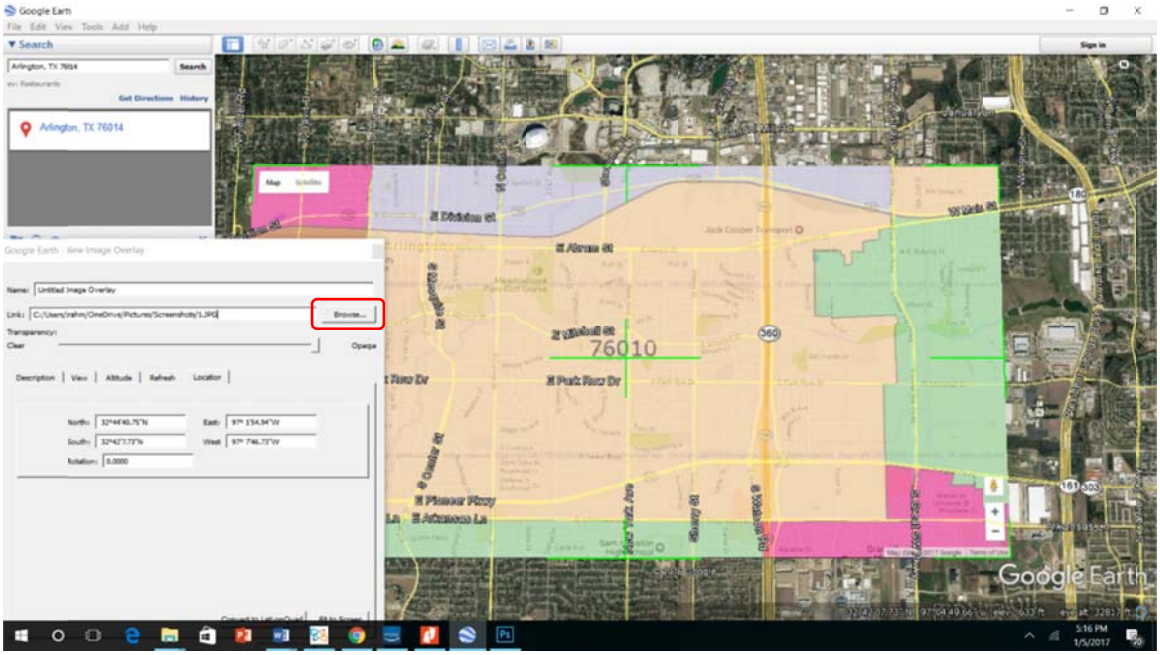


Figure H.3: Modifying the features of the overlaid image

d. Change the transparency of the layer if necessary when fitting the jpeg image on the map
e. Use the mouse for dragging the four sides of the jpeg file and match to the background Google Earth layer as close as possible.
f. Download the .kml file from the Safe Activity app and open the layer.

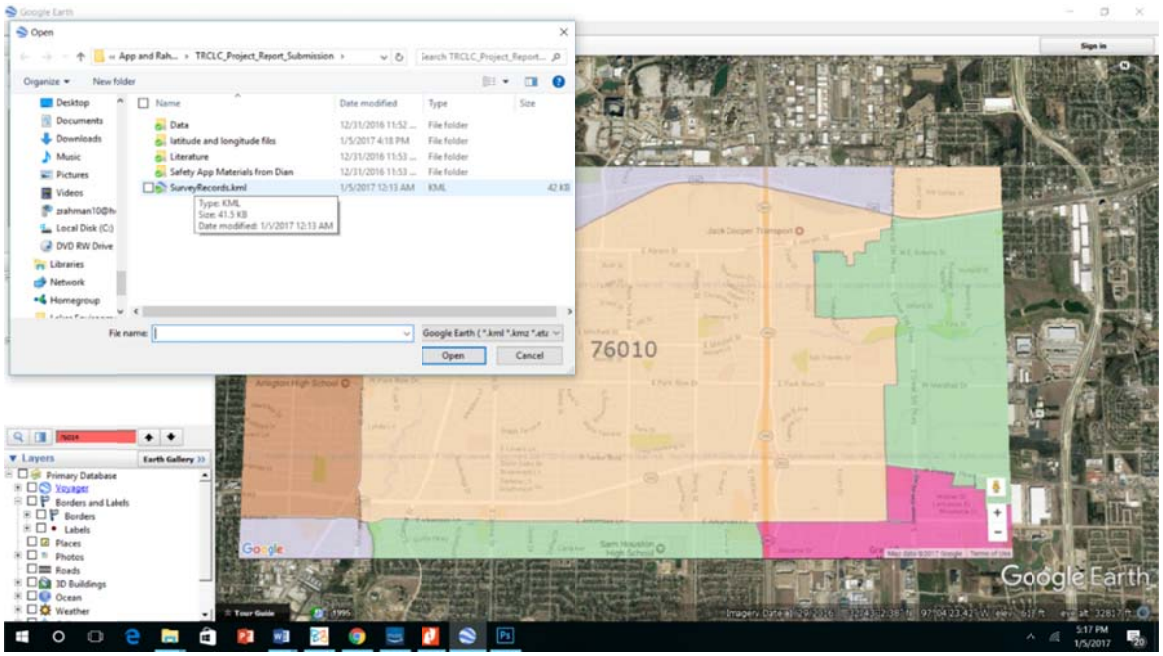


Figure H.4: Adding the downloaded kml file in Google Earth

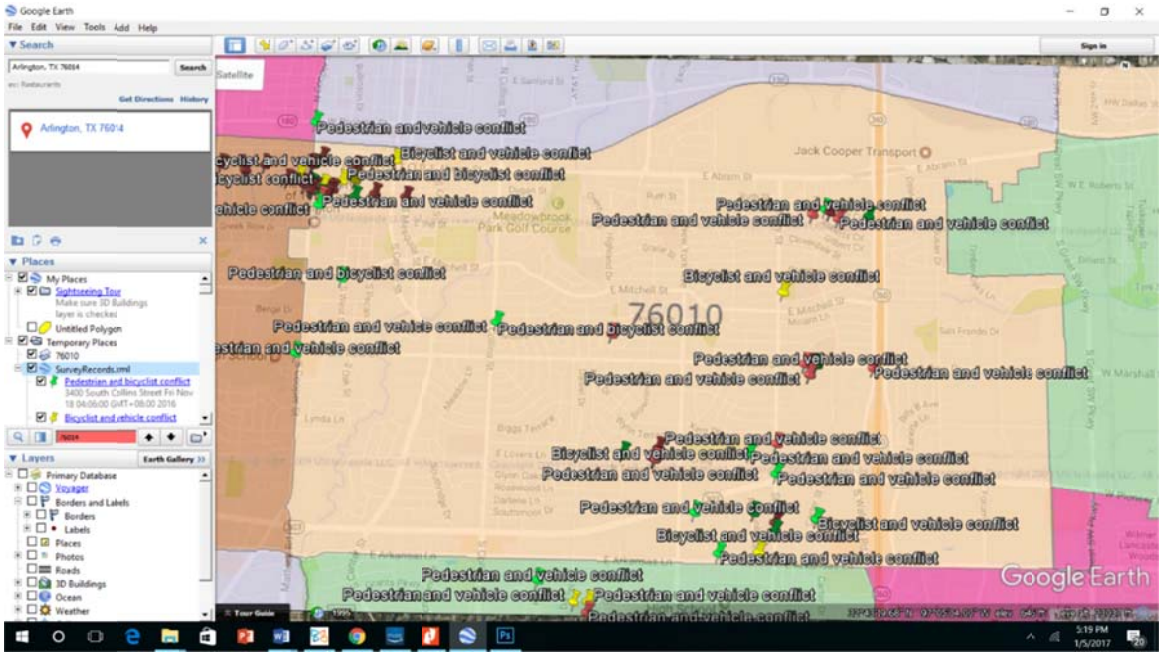


Figure H.5: Zip code image layer and conflict records layers together in Google Earth

Following this procedure will help the users get a Google Earth map where Mr. Doe can identify conflict records that occurred in 76010 and do spatial analysis. If further analyses are required from the data itself, users can move forward and use the Excel file. Filtering column "W" which holds the source Zip code, the users can easily isolate conflicts associated with a specific zip code.

Getting data from any Polygon

After the initial investigation, Mr. Doe identified a specific area where the conflicts are concentrated. Now he wants to perform a more detailed analysis in that rectangular area. The following steps are considered while do this-

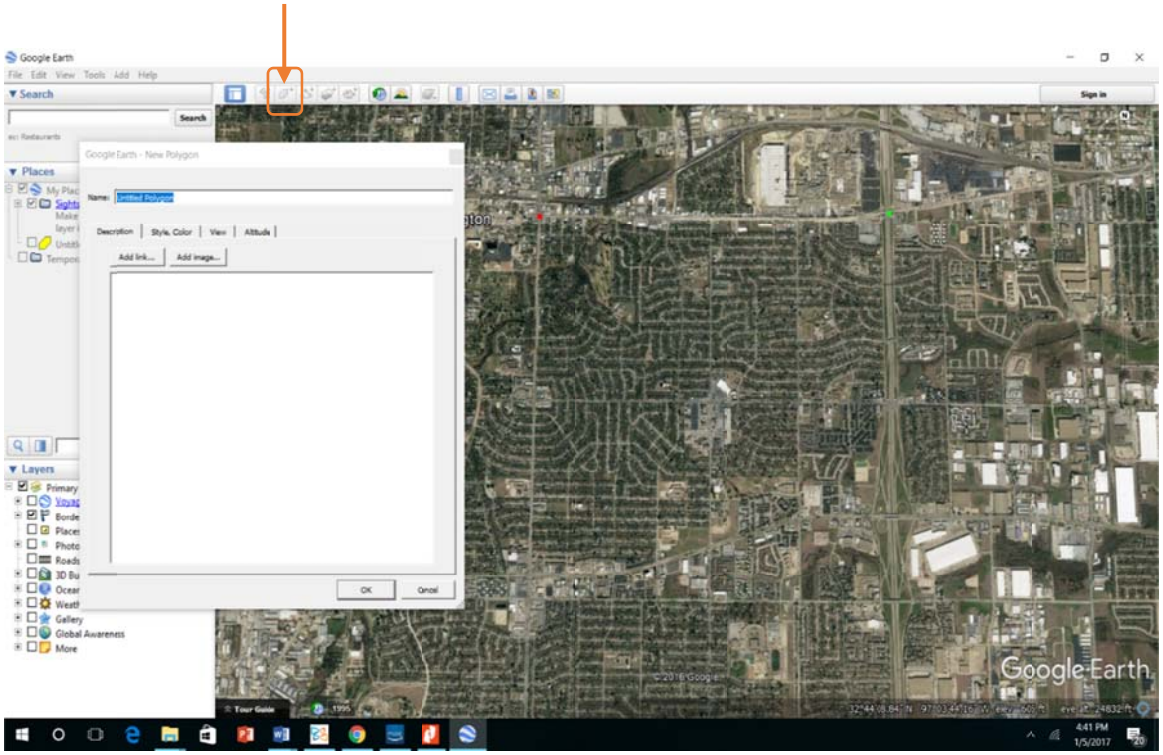


Figure H.6: Adding Polygon area on Google Earth

a. Open *New Polygon* window and place it exactly to the four corners of the rectangular area of the study area

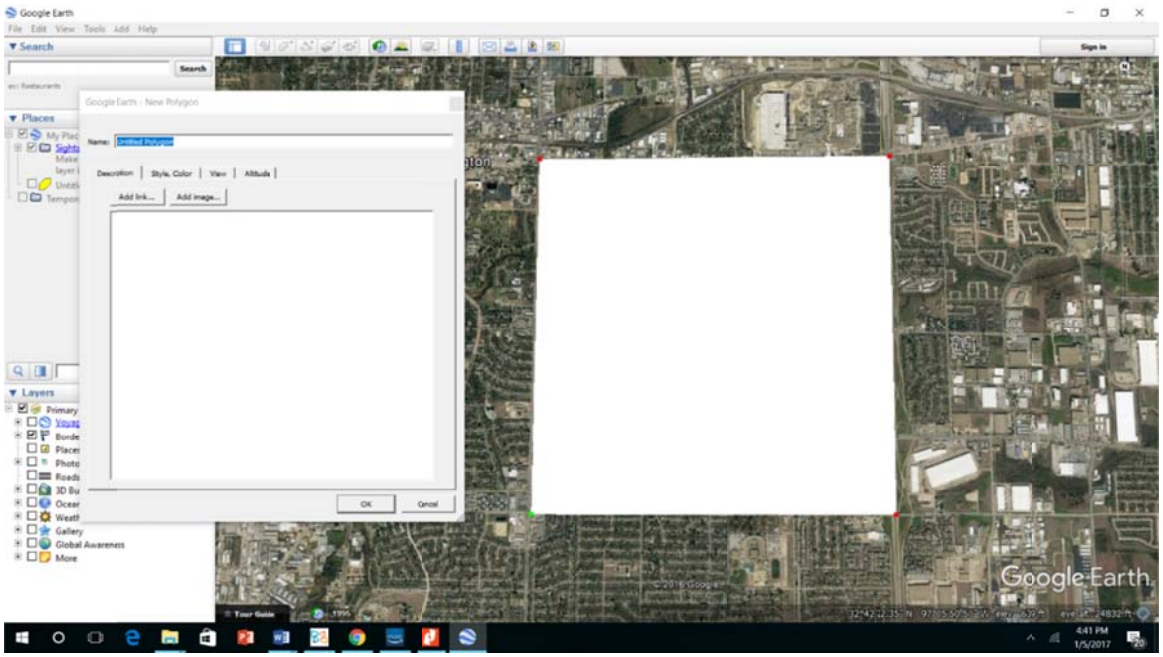


Figure H.7: Drag and position each corner on desired locations

b. Change the *Style*, Color of the Polygon with some Translucent background

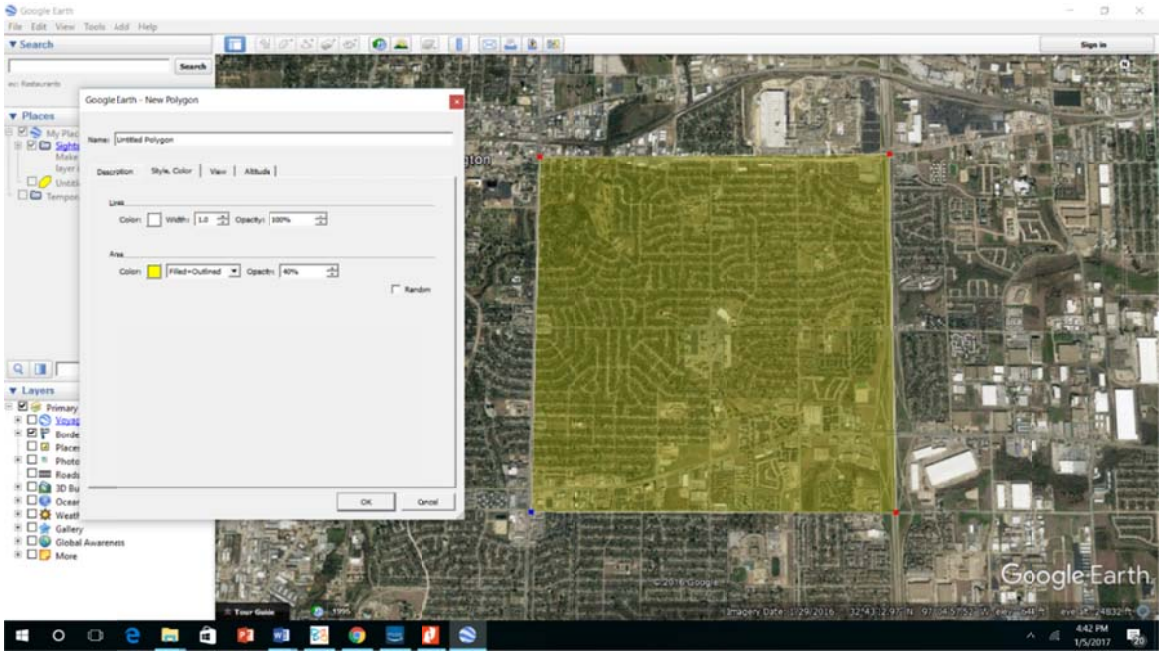


Figure H.8: Changing styles of the polygon

c. Open the SurveyRecords.kml layer in Google Earth

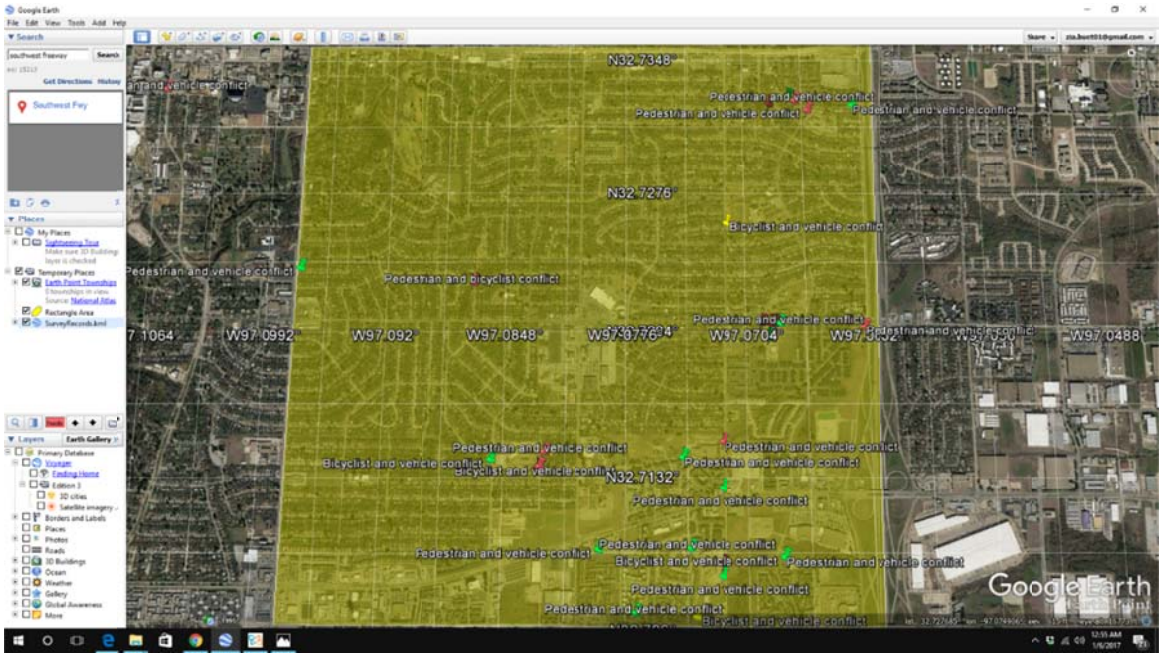


Figure H.9: Conflict records inside the polygon area

d. Open *New Placemark* window for marking four corners of the rectangle.

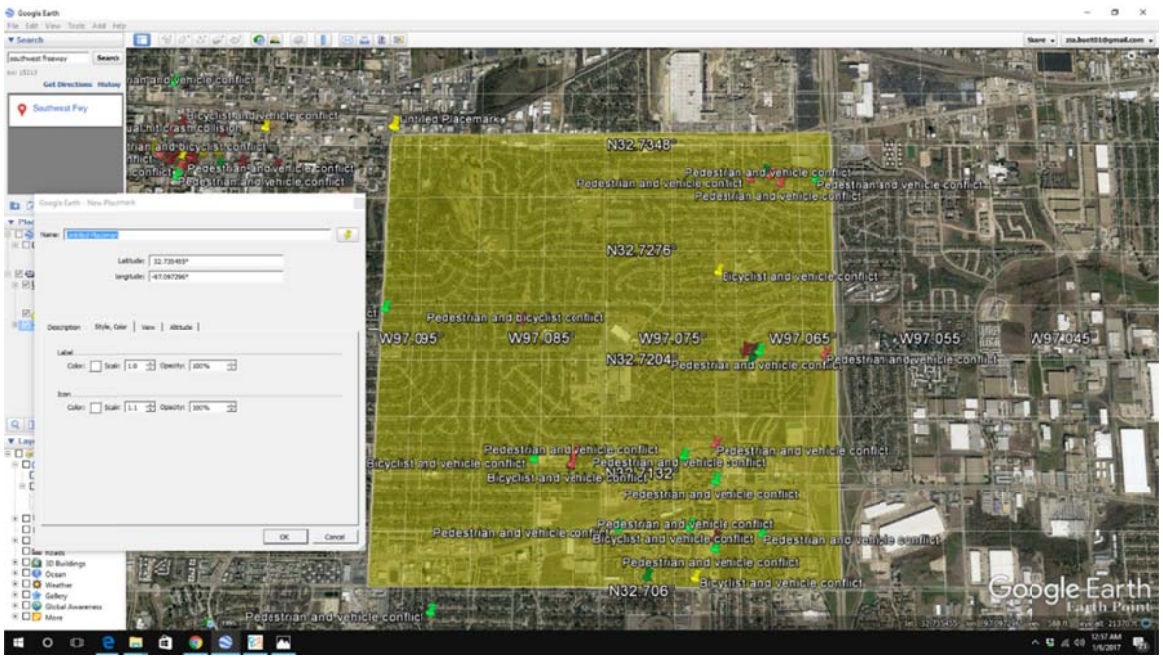


Figure H.10: Marking four corners of the polygon area for Latitude and longitude

e. Mark all four corners and jot down the Latitude and Longitude of the area

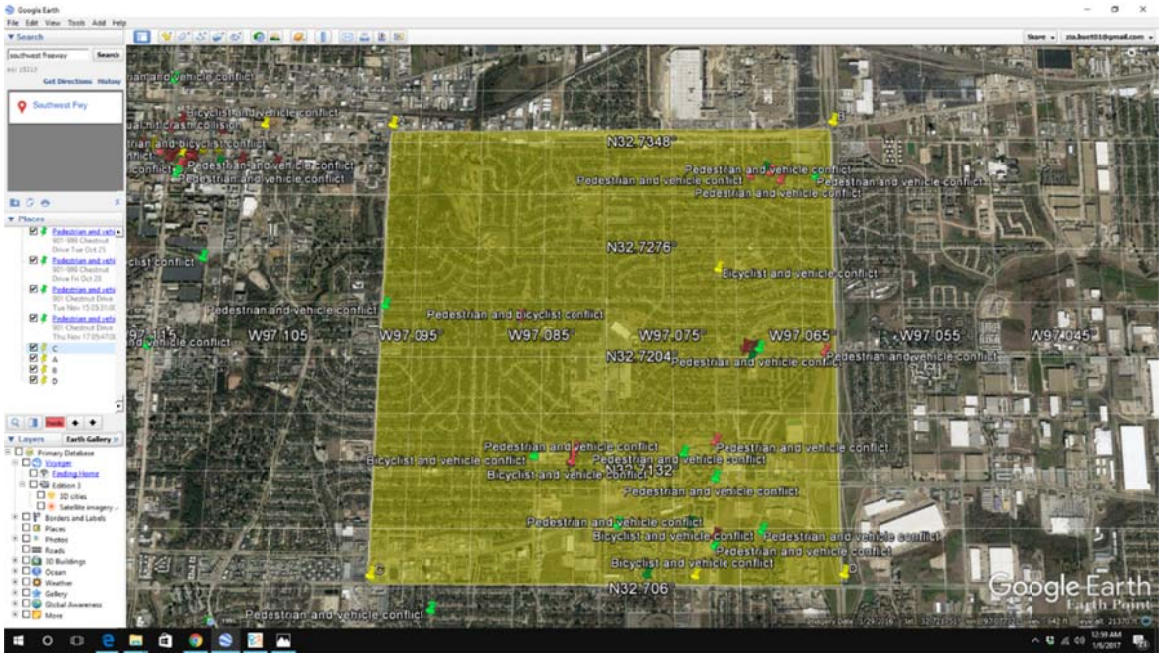


Figure H.11: Completed polygon area and the conflict records inside the area

Table H.1: The latitude and longitude of the polygon area

	A	B	C	D
Latitude	32.735455 °	32.735613 °	32.706269 °	32.70625 °
Longitude	-97.097344 °	-97.062434 °	-97.097562 °	-97.062690 °

Using these latitude-longitude information, Mr. Doe can separate the conflicts that occurred inside this area and do conflict analysis. The following Excel code is just an example in this case to show how the coordinates of a specific rectangle can be used to isolate the conflicts for further analysis.

=IF(AND(T2<32.735613, T2>32.70625, U2>-97.097562, U2<-97.062434),1, 0)

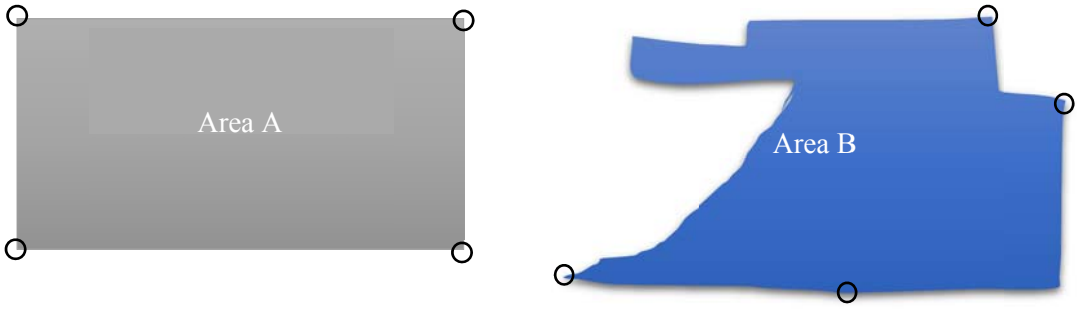


Figure H.12: Example of shape of the study area

This helps policymakers and researchers not only visualize the pattern of conflicts in a Google map but it enhances the analysis procedure when exported into Excel. This equation is true for regions north of the equatorial line and western hemisphere as in west of Prime Meridian. As for the geographical position of the North Western Hemisphere, whenever an area is selected, the latitude of A and C always increases from south to north or from the equatorial line towards upwards. This is also true for the latitude of B and D. The longitudinal coordinates increase negatively from B to A and the same for D to C. Because of this pattern, when writing the equation, the extreme values of the coordinates of point ABC and D should be selected. This holds true even if the area is a polygon. For a polygon area, a more elaborate equation is necessary for identifying the different arms of the polygon.