Introduction of Geocoding Collisions in California and Its Possible Application in Korea

Shin Hyoung PARK
Ph.D Candidate
Department of Civil and Environmental Engineering
Seoul National University
Bldg.135-402, 599 Gwanak-ro,
Gwanak-gu, Seoul, Korea, 151-744
Fax: +82-2-889-0032
E-mail: shpark76@snu.ac.kr

John M. BIGHAM
MPH, Research Associate
Traffic Safety Center
University of California at Berkeley
2614 Dwight Way #7374
Berkeley, CA, USA, 94720-734
Fax: +1-510-643-9922
E-mail: jbigham@berkeley.edu

Abstract: Collision geocoding is a process of finding exact accident locations from other geographic data such as street address, zip codes, and postmile in traffic collision records. Through this process, the geocoded accident locations can be mapped onto digital maps based on Geographic Information Systems (GIS), and the results can be used for various purposes like displaying informative collision maps and conducting spatial analyses. Recently, in California, there was an effort to geocode collision data obtained from the Statewide Integrated Traffic Records System (SWITRS) and the overall match rate was 91%. The availability of geocoded collision data will be beneficial to clinicians, researchers, policymakers, and practitioners in the fields of traffic safety and public health. Therefore, in this paper, we will introduce the geocoding method and explore how to apply it to Korean situation by comparing road and address systems of Korea with those of the U.S.

Key Words: geocoding, GIS, crash mapping

1. INTRODUCTION

In the U.S., each of the states maintains an electronic police collision report database. In California, the California Highway Patrol (CHP) enters accident data from CHP-generated reports as well as those from local police departments, into the Statewide Integrated Traffic Records System (SWITRS). These collision data are extensively used by law enforcement, researchers, and injury prevention practitioners to monitor collision rates, identify hazardous locations, and develop and evaluate traffic safety programs (Bigham et al., 2009).

Geocoding, which is also known as address matching, is a process of assigning geographic descriptors (usually latitude and longitude coordinates) to the information of places (ESRI, 2003a). In the field of Traffic Safety, this ‘place’ can be a location where an accident occurred. Therefore, geocoding accident data indicates the process of finding the exact collision locations from other geographic data such as street address, zip codes (postal codes), and postmile in traffic collision records. Through this process, the geocoded accident points can be mapped onto digital maps based on the Geographic Information Systems (GIS) and the results can be used for various purposes like displaying the accident data and conducting spatial analyses.

A few efforts have been made in the U.S. to develop comprehensive crash mapping and analysis systems that incorporate geocoded data as a part of the systems. The Rutgers Center for Advanced Infrastructure and Transportation completed a statewide geocoding for the New Jersey Department of Transportation (DOT) and built a crash analysis tool for New Jersey
Departments of Public Works (CAIT, 2009). The Planning Section of the Connecticut DOT geocoded the crash records in the statewide system developed for the Crash Outcome Data Evaluation Systems (CODES) national initiative (Cromley et al., 1998). However, these reports focus on the applications and their functionality rather than the geocoding methods. (Bigham et al., 2009)

There are other examples of research that outline the geocoding process for collision data. Dutta et al. (2007) developed a system to automate the geocoding of collision data based on existing maps and crash forms used by the Wisconsin Department of Transportation. Likewise, there were several efforts made to geocode collisions and create a custom geocoding tools for collision data in three different counties of Florida (Steiner et al., 2003; Zhan, 2005; Zhan et al., 2006).

In this paper, based on the efforts to geocode fatal and severe injury collisions in California from 1997 to 2006, an effective and efficient geocoding methodology is introduced and proposed. Furthermore, this paper demonstrates environmental and technical differences between South Korea and the U.S., and thus sets up a basis to apply this methodology to Korean accident management systems.

2. METHODS

2.1 Overview
To complete geocoding tasks, different methods were applied to each of state highway collisions and local road collisions respectively. State highway collisions are coded with a numerical value that corresponds to the postmile system used on the California state highway system, while local road collisions are coded with the primary and secondary street names of the nearest intersection, the collision’s direction, and distance from the intersection. In addition, postal addresses are occasionally used. Figure 1 shows the 5 coding scenarios that are used for the vast majority of SWITRS collisions.

<table>
<thead>
<tr>
<th>Address</th>
<th>PRIMARY(^{a})</th>
<th>SECONDARY(^{b})</th>
<th>(^{a}) PRIMARY STREET NAME</th>
<th>(^{b}) SECONDARY STREET NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection without Offset</td>
<td>PRIMARY</td>
<td>SECONDARY</td>
<td>INTERSECTION</td>
<td>DISTANCE</td>
</tr>
<tr>
<td>MAIN ST</td>
<td>MAIN ST 1ST AVE</td>
<td>YES</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Intersection with Offset</td>
<td>PRIMARY</td>
<td>SECONDARY</td>
<td>INTERSECTION</td>
<td>DISTANCE</td>
</tr>
<tr>
<td>MAIN ST</td>
<td>MAIN ST 1ST AVE</td>
<td>NO</td>
<td>50</td>
<td>EAST</td>
</tr>
<tr>
<td>State Route with Postmile</td>
<td>State HW(^{c})</td>
<td>Route #</td>
<td>Postmile</td>
<td>Side of HW</td>
</tr>
<tr>
<td>YES</td>
<td>5</td>
<td>33.567</td>
<td>SOUTH</td>
<td></td>
</tr>
<tr>
<td>Fixed Object</td>
<td>PRIMARY</td>
<td>SECONDARY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAIN ST</td>
<td>LIGHT POLE 1933</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 Examples of collision location information for 5 coding scenarios

The geocoding were completed by a multi-step process. First, pre-processing was performed using a scripting language to clean and standardize street name information. As a next step, for the highway collisions, a highway network was created based on the StreetMapPro 2003 (ESRI, 2003b) digital street network and calibrated with postmile values. To perform the
process of route creation and calibration easily and correctly, customized tools written in Visual Basic for Applications (VBA) in ArcGIS 9.2 software (ESRI, 2008) were used. ArcGIS VBA provides an integrated programming environment to build tools that complement the standard ArcGIS software. Collisions were then geocoded using linear referencing method. For the local road collisions, the data set of collision records was subsetted into separate files to undergo Intersection and address geocoding. Custom VBA functionality was also used not only to incorporate the off-set direction and distance but also to geocode collisions. Finally, additional collisions were geocoded using the Google Earth Pro (Google, 2008) software. All records were then appended into one data file which had two additional new variables - latitude and longitude coordinate values.

2.2 Data sources
Geographic information on California highways and local roads was obtained from StreetMap Pro 2003 and a 2008 TeleAtlas-based street network was accessed through Google Earth Pro. Postmile locations of major intersections, entrance ramps, and exit ramps for all state highways were obtained from the California Highway Performance Monitoring System (HPMS, 2008). These data are essentially required to input correct postmile values and thus calibrate routes to use linear referencing.

Data on all fatal and severe injury collisions except for light injuries and Property Damage Only (PDO) on public roadways in California from 1997 to 2006 were obtained from the Statewide Integrated Traffic Records System (SWITRS) (CHP, 2008).

<table>
<thead>
<tr>
<th>Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIS</td>
<td>StreetMap Pro 2003</td>
</tr>
<tr>
<td></td>
<td>· Geographic information on California highways and local roads</td>
</tr>
<tr>
<td></td>
<td>· TeleAtlas-based street network that ESRI software license holders could obtain for free</td>
</tr>
<tr>
<td></td>
<td>2008 TeleAtlas-based street network</td>
</tr>
<tr>
<td></td>
<td>· accessible through Google Earth Pro</td>
</tr>
<tr>
<td>California Postmile Reference</td>
<td>· Postmile locations of major intersections, entrance ramps, and exit ramps for all state highways</td>
</tr>
<tr>
<td></td>
<td>· obtained from the California Highway Performance Monitoring System (HPMS)</td>
</tr>
<tr>
<td>Accident</td>
<td>SWITRS</td>
</tr>
<tr>
<td></td>
<td>· StateWide Integrated Traffic Records System</td>
</tr>
<tr>
<td></td>
<td>· fatal and severe injury collisions on public roadways in California from 1997 to 2006</td>
</tr>
</tbody>
</table>

2.3 Pre-processing
In order to process the collision location information and match the highest possible number of collisions, several pre-processing steps need to be completed prior to implementing the geocoding procedures. Since SWITRS data is collected from CHP or local law enforcement officials and input into the database at a central location for the entire state, manual entry of collision records may include different types of errors or descriptions that are invalid for locating the collision. Therefore, by pre-processing, these invalid entries can be corrected and thus the geocoding process will have a much higher accuracy.

The pre-processing performs text changes on common errors using Perl (2008), a text-oriented language. These errors were identified by reviewing samples of collisions that were
unable to be geocoded during preliminary attempts. After cleaning the data, it was then exported to a database file that can be used for geocoding. Pre-processing steps include:

- Fixing common misspellings
- Removing unnecessary symbols or characters in the street name
  - Hyphens (e.g., ‘AVE J-5’ did not geocode, whereas ‘AVE J5’ did geocode)
  - Symbols or characters (e.g., ‘*.STATE ST’)
- Removing entries with invalid streets
  - Street information may contain locators such as a light pole or fire hydrant which cannot be geocoded
- Interpreting exact addresses from primary and secondary fields

2.4 Postmile geocoding
The California postmile reference system tracks the mileage all state highways travel through each county in the state. The postmile typically begins at 0 in the southern or western boundary of the county and increases until reaching the opposite county boundary. The postmile system provides an accurate locational reference for any events that occur along the state highways. In order to utilize this postmile designation for geocoding, the street network must have knowledge of the postmile system. Once the street network included the postmile values, a custom linear referencing process was used to place the collisions along the state routes.

2.4.1 Building a base state highway network (Route Creation)
The first step for postmile geocoding was route creation which builds a continuous state highway street network. Each state highway in StreetMap Pro consists of sequential segments that share the same route number and direction. In order to use ArcGIS’s linear referencing functionality, the segments must be joined into a single line feature for each county (Figure 2).

This was a semi-automated process that required frequent manual intervention to deal with a range of exceptions; direction changes, two segments merging into a single segment, and naming changes. Also, California uses a separate postmile numbering system for each county. The merged line features were thus split by county and then, unique route identifiers were assigned to each split route. The identifier contains the route number, direction and county, e.g. ‘80E-ALAMEDA’.

2.4.2 Adding postmile values to the network (Route Calibration)
After building the state highway network, postmile values were added to reference points along the highways. Reference points were automatically generated using a custom ArcGIS tool and interface (Figure 3) where exit/entrance ramp segments intersected the state routes.
highways. The tool allowed users to select a reference point, open a dialog interface, and enter an ID value for a feature (e.g., an entrance ramp). The tool then saved the ID and the postmile value to the state highway network. Other points for county boundaries and some intersections were manually added to enhance the accuracy of route calibration.

The postmile values added for the reference points on the street network were visually matched to the descriptive reference in the HPMS system. 15,969 postmile markers were added in total. The frequency and distance between postmile reference points varied by individual highways. Typically, interstate highways had shorter distances between reference points than small state highways, particularly those in rural or mountainous regions.

2.4.3 Checking for postmile value errors
To check the positional accuracy of the postmile values, an automated error checking procedure was created, which identified possible problems by verifying the monotonic
correlation of postmile values with their latitude or longitude progression. The latitude or longitude coordinate for each reference point was extracted and added to a spreadsheet table and sorted by county and highway direction. An excel macro tool then confirmed the monotonic sequence. Potential errors were flagged and manually reviewed. A final check was conducted by searching for unlikely clusters of collisions between certain postmile values which indicated a potential problem.

2.4.4 Geocoding collisions through linear referencing
Postmile-coded collisions were geocoded using the ArcGIS linear referencing tools to match the collision postmile to the calibrated highway network. Linear referencing is the method of storing geographic locations by using relative positions along a measured linear feature (ESRI, 2008). Distance measures are used to locate events along the line. Many locations are recorded as events along linear features – for example, locations of traffic accidents are geocoded using collision information such as 10 miles from the reference postmile marker 0 along Interstate Highway 80 East (Figure 5).

Figure 6 shows an example of collision data geocoded on state highway I-50 in Sacramento County. Red points mark collisions occurred on I-50 and green points represent postmile markers.

![Figure 5 An example of Linear Referencing](image_url)

![Figure 6 An example of collision data overlaid on state highways](image_url)
2.5 Intersection & Address Geocoding

2.5.1 ArcGIS Geocoding
ArcGIS software was used to geocode intersection- and postal address-coded collisions. A geocoder provided by ArcGIS is created using the street network that specifies how to match an address to its geographic street location. Ideally, the intersection address will exactly match a specific point on the street network. However, this is not always the case due to different spellings, typos or directional ambiguities or other factors. Therefore, the geocoder assigns a match score to each collision record. This score is based on weights specified in the geocoder for different components of the street address (e.g., street name, type, city, prefix or suffix), and standardized from 1 to 100. For our analysis, we gave higher weights to street name and the city and devalued fields such as street type or suffixes since they are not as important for an accurate match. A match score threshold of 65 was designated based on our custom weights and all geocoded records with a match score above 65, including ‘ties’ were retained. Ties could be generally happened when dual line roads intersected other roads, because a single intersection may have at least 2 points that have the same score and any of the points would be valid for the geocoding match. In addition, a few streets occasionally intersect with another street at more than one location. It is impossible to distinguish which intersection is the actual intersection indicated in the SWITRS record.

The remaining data that is unmatched may fail for a variety of reasons. The intersection may not actually exist, the entry may contain egregious misspellings or the Streetmap pro road network does not have the latest streets for that intersection. To geocode more of these non-matches, the dataset is subsequently exported from ArcGIS to a new table for use with Google geocoding software.

2.5.2 Google Earth Pro Geocoding
Google provides the capability to geocode a list of addresses and the most up to date street networks. By running the non-matches using Google’s geocoding algorithm, many of the entries could be matched. However, after test trials, it was evident that Google is also prone to false positive matches. It means that if Google was used for the initial geocoding prior to ArcGIS there would be a large amount of incorrectly placed data. On the other hand, by reducing the list to a much smaller number of intersections, we were able to better manage any false positives.

Several trials showed that when Google incorrectly placed a match, it was usually substantially incorrect. For example, several matches were placed in Canada due to the ‘CA’ state entry in the address. However, if a location was placed in the correct county then they appeared to be accurate. Therefore, the matched data was then imported into ArcGIS for county verification. The points were overlaid with a county map layer to verify that the county it was placed in matches the county field variable. If they did not match, the points were removed and considered non-matchable.

A final step was assuring the coordinates of the matched points fall exactly along the Streetmap Pro street network. Since Streetmap Pro may not exactly match the street network used by Google, the XY coordinates of a collision were required to be adjusted. Therefore, we programmatically snapped all points within a 20 meter distance to the nearest intersection. Locations that fell outside of the tolerance distance or were made on newer roads that did not exist in StreetMap Pro could not be snapped and were left unchanged. All matched data was then appended into a complete dataset.
### 2.6 Offset Calculation
Collisions that did not occur at an intersection will include the offset distance and direction from the nearest intersection. This offset was often ignored during geocoding process and the collisions were simply mapped to the nearest intersection. A custom method for incorporating this offset was developed using linear referencing tools in ArcGIS. The methodology employed was similar to Steiner *et al.* (2003). The first step was to define a new linear referencing system based on all connected segments in each county with the same name. The lower left corner of the segment was defined as the starting point at 0 distance and distance accumulated along the length of the segment. The direction of the segment was determined based on whether the vertical or horizontal distance of the segment was longer. For example, if the vertical distance exceeded the horizontal distance, the direction was assigned as South-to-North. Next, the database of collisions geocoded to the nearest intersection was examined; and for each collision, all line segments that intersect the collision were selected as candidates. A single segment was chosen for each collision based on the matching primary street name and direction. Finally, the offset distance was calculated for the collision. The offset distance was added to the starting point of the segment for North and East directions, while offset distances for South or West directions were subtracted from the ending point of the segment. The collision was then adjusted the correct distance via linear referencing. (Bigham *et al.*, 2009)

### 3. RESULTS
A collision geocoding attempt was judged to be a match if each record met one of following five conditions corresponding to its type in Table 2.

<table>
<thead>
<tr>
<th>Record Type</th>
<th>Match Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>an intersection- and address-coded record</td>
<td>scored a match score of 65 or higher based on the custom ArcGIS weights</td>
</tr>
<tr>
<td></td>
<td>scored a ‘tie’ match score of 65 or higher</td>
</tr>
<tr>
<td>an intersection-coded record</td>
<td>was geocoded by Google Earth Pro and satisfied the filtering process</td>
</tr>
<tr>
<td></td>
<td>geocoded in ArcGIS or Google Earth Pro that required an offset adjustment satisfied the filtering process</td>
</tr>
<tr>
<td>a postmile-coded record</td>
<td>presented no error during linear referencing</td>
</tr>
</tbody>
</table>

A total of 142,007 fatal and severe injury collisions were identified in SWITRS from 1997 to 2006. Results for all years were similar. Of those collisions, a total of 14,933 fatal and severe injury collision records were obtained from SWITRS for 2004. 9,409 (63%) were local road collisions geocoded by intersection street names and 5,524 (37%) were state highways geocoded by postmile value. Overall, 13,620 (91%) were successfully geocoded. Table 3 provides detailed results for each component of the process.
Table 3 Geocoding results

<table>
<thead>
<tr>
<th>Process</th>
<th>Match</th>
<th>Non-match</th>
<th>Total</th>
<th>Match-rate (%)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Known Incompatibilities</td>
<td>-</td>
<td>39</td>
<td>39</td>
<td>0</td>
<td>not included in digital street networks</td>
</tr>
<tr>
<td>Exact Addresses</td>
<td>59</td>
<td>4</td>
<td>63</td>
<td>93.65</td>
<td>None of these records would have been geocoded without pre-processing</td>
</tr>
<tr>
<td>Intersections</td>
<td>2,919</td>
<td>723</td>
<td>3,641</td>
<td>80.17</td>
<td>Records not geocoded using ArcGIS were geocoded using Google Earth Pro</td>
</tr>
<tr>
<td>Intersection Offset</td>
<td>5,130</td>
<td>535</td>
<td>5,665</td>
<td>90.56</td>
<td>A majority of the invalid entries were distances that would place the collision beyond the end of the street.</td>
</tr>
<tr>
<td>Sub-total</td>
<td>8,108</td>
<td>1,301</td>
<td>9,409</td>
<td>86.17</td>
<td>Twelve non-matched collisions included egregious postmile errors, incorrect route numbers (nonexistent within county), or occurred on newly constructed highways not yet included in the street network</td>
</tr>
<tr>
<td>Postmile Collisions</td>
<td>5,512</td>
<td>12</td>
<td>5,524</td>
<td>99.78</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13,620</td>
<td>1,313</td>
<td>14,933</td>
<td>91.21</td>
<td></td>
</tr>
</tbody>
</table>

4. DISCUSSION

4.1 Comparison of Address Systems between Korea and the U.S.

The present address system of Korea is based on land-lot numbers, whereas that of the U.S. is based on the street names.

Table 4 shows components and examples of the each address system currently used in Korea and the U.S. As can be seen in the table, these two systems look somewhat similar. Although the elements of the each system are not placed in the same order, both of the systems generally consist of 6 elements and sometimes shaded elements in the table can be omitted in the case of a detached house. In addition, a postal code (zip code), district information such as a city name, a building name, and a unit number are included in both systems.

Table 4 Address systems of Korea and the U.S.

<table>
<thead>
<tr>
<th>Korea</th>
<th>Si, Do</th>
<th>Si, Gun, Gu</th>
<th>Eub, Myun, Dong</th>
<th>Bunji (Land-lot Number)</th>
<th>Building name</th>
<th>Postal code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Seoul</td>
<td>Gwanak</td>
<td>Shillim</td>
<td>San 56-1</td>
<td>Bldg. 135-402</td>
<td>151-742</td>
</tr>
<tr>
<td>The U.S.</td>
<td>Building Number</td>
<td>Street</td>
<td>Building &amp; Unit Number</td>
<td>City</td>
<td>State</td>
<td>Zip code</td>
</tr>
<tr>
<td>Example</td>
<td>555</td>
<td>Pierce st.</td>
<td>Apt. #329</td>
<td>Albany</td>
<td>California</td>
<td>94706</td>
</tr>
</tbody>
</table>

On the other hand, there are a few differences between these two systems except for the order of the components. In Korea, the first three items (Si, Gu, and Dong) are assigned to express administrative districts, but two items (City and State) are used for them in the U.S. system. However, the most remarkable difference is that Korean system uses a land-lot number as an
identifier of an exact location, while American system uses a street name and building number. This is exceedingly important because the land-lot number based address system cannot sustain its number when a parcel is partitioned into several lots or inversely adjacent lots merged into big one. That is, as time goes by, no consistency or continuity between land-lot numbers is getting disappeared. In the street name based address system, on the contrary, all of the building numbers are assigned in regular sequence by following direction from a starting point of a street. For example, if there is a street named University Avenue which is eastbound, buildings on the northern side have odd numbers and buildings on the southern side have even numbers. Therefore, by using this address system, it is really easy to find exact locations as well as maintain and manage the address system efficiently and systematically.

By this reason, in Korea, the new address system based on the street names is under construction and the two address systems are used together at present. Furthermore, only the new address system will be used from January, 2012.

4.2 Comparison of Highway Systems between Korea and the U.S.
Building network data as well as geocoding highway collisions of Korean highway is much easier than that of California State Highway because (1) the land area of South Korea is one fourth of that of California, the number of highway routes is only 26, and thus the total length of Korean highways is far shorter than that of California state highways; (2) Korean highway uses a single mileage system per each route, whereas each county in California uses separate postmile system even on the same route; (3) almost of Korean highways are being operated as expressway and tollway, so they are physically separated from local streets to raise speed and safety as well as to collect tolls. Therefore, the network data can be built relatively at a small cost in a short time and highway collisions can be geocoded using linear referencing functionality in the same manner as California.

4.3 The Applicability of the Geocoding Method for Domestic Use
Based on above comparisons of address and highway systems between Korea and the U.S., the geocoding method used in California can be applied as follows:

1. For local street collisions, this method cannot be used in Korea due to different address system from the U.S. However, when the new address system is completely established and enforced in 2012, it will be applicable to domestic geocoding systems.

2. For highway collisions, on the contrary, this method can be applied immediately. The location of each collision is recorded with highway route number, direction and postmile (actually postkilometer in Korea). In addition, since the highway system is being operated as expressway and tollway which is physically separated from local roads in almost of highway sections, network data can be easily built compared to the California state highways and also the customized ArcGIS tools can be utilized with simple modifications.

5. CONCLUSION

In this paper, we introduced geocoding methods to find exact locations of collisions occurred on the state highway and local streets in California. We were able to geocode 91% of 142,007 California fatal and severe injury collisions identified in SWITRS from 1997 to 2006. The effort resulted in a statewide, public-use database of geocoded collision data that should be useful for injury prevention research and practice. A second primary outcome was the creation of a postmile-based, digital street network for the California State Highway system to facilitate the use of linear referencing methods for geocoding highway collisions and other...
events or objects. The use of this street network in the current project allowed for a geocoding success rate of 99.8% for state highway collisions, compared with 86% of collisions geocoded by intersection and address.

These outcomes support the necessity of applying the geocoding method to Korean collision mapping systems. Comparing Korean address and highway systems with American systems, this method can be immediately applicable to the geocoding of highway collision data relatively at a small cost in a short time with simple modifications to the Custom ArcGIS tools. For local street collisions, although currently it is too early to apply the geocoding method due to the different address system from the U.S., it can be considered when the new address system is completely constructed in the near future.

The availability of geocoded collision data will be beneficial to researchers, policymakers, and practitioners in the fields of traffic safety and public health. Professionals familiar with geocoding will save time and resources by skipping the first step of their analyses. Transportation engineers can use the data to investigate collision clusters along state highway routes in relation to carpool lanes, road construction projects, wet surface spots, hazardous locations, or other factors. Social workers can review associations between collision locations and land use characteristics. Alcohol researchers can examine the proximity to alcohol outlets to collisions with alcohol use among drivers or pedestrians. The ability to provide map outputs may make significant contributions to planning and conducting research to inform data users, and to explore potential policy (Bigham et al., 2009).

A follow-up research project will mainly focus on spatial analyses of the geocoded collisions based on the collision characteristics recorded in the accident database, while partly making improvements to the geocoding process by performing enhanced customization to the street network.

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