KSCE Journal of Civil Engineering (2011) 15(8):1435-1441
DOI 10.1007/s12205-011-1401-8

Transportation Engineering

www.springer.com/12205

Geocoding Vehicle Collisions on Korean Expressways Based on Postmile Referencing

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Received November 23, 2010/Accepted February 17, 2011

Abstract

Geocoding is the process of assigning latitude and longitude coordinates to data that contain spatial information. Geocoded records of motor vehicle collisions are an invaluable resource for injury prevention researchers. The objective of this study is to apply the postmile referencing system for geocoding collisions on Korean expressways and summarize the methodology and results with comparative research efforts in the USA. A street network provided by Korea Expressway Corporation was cleaned and calibrated using ArcGIS and a customized Visual Basic for Applications (VBA) tool. Geocoding via postmile referencing was determined to develop the most appropriate methodology for Korean expressways. A database of expressway collisions from 2003 to 2008 was geocoded, and 24,854 out of 24,879 (99.9%) collisions were successfully matched to the street network. This study established an effective methodology for geocoding collisions on Korean expressways. Future research will benefit from the development of a street network that can be updated over time to incorporate newly constructed roads. The methods for street network cleaning and error checking and the use of linear referencing to geocode collisions are easily transferable to highway networks in other countries. The geocoded database of expressway collisions can be used for numerous traffic safety improvement programs and help reduce fatalities.

Keywords: *geocoding, expressway collisions, linear referencing, postmile markers, traffic safety*

1. Introduction

Geocoding is the process of assigning latitude and longitude coordinates to data that contain spatial information. Geographic descriptors, such as addresses, street intersections, and highway postmile or kilometer post markers can be geocoded onto a digital map with the aid of Geographic Information Systems (GIS) software tools. The ability to visualize the spatial relationships within datasets can be essential to many types of research. In the public health sector, geocoding of the locations of disease outbreaks can help analyze geographic patterns of the disease incidence (Rushton *et al*., 2004). Criminal activity can be geocoded to determine the locations of crimes and help detect patterns that can be used to develop successful preventative measures (Craglia *et al*., 2000).

In the traffic safety field, geocoded records of motor vehicle collisions are an invaluable resource for injury prevention researchers. The records can be used to identify the locations at which collisions occur frequently, and this information can be used to prioritize projects designed to improve road safety. Collisions can be analyzed in connection to neighboring areas to determine the density of alcohol-related collisions relative to the number of alcohol outlets in the area. The results of such research can lead to policy changes for the purpose of enforcement, education, prevention, and budgeting related to alcohol-related collisions.

A variety of geocoding methodologies exists, and extensive research has been conducted to determine best practices for geocoding data along roadways. Geocoding methods have been applied by using factors including addresses, intersections and offsets, longitude and latitude coordinates, and postmile values depending on what could be used as geographic descriptors.

The purpose of this paper is to apply the postmile referencing

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system for geocoding collisions on Korean expressways. After examining the existing literature, kilometer post linear referencing was deemed to be the most suitable method for cataloguing collisions that occur along the expressways. The methodology and spatial match accuracy of the final geocoded dataset were compared with recently completed research performed by Bigham *et al.* (2009) in the state of California for the evaluation of methodological appropriateness.

This paper is structured as follows: Published geocoding methods and examples are compared in Section 2 in order to select the most appropriate geocoding method for Korean expressways. Section 3 describes the street network data and records of collisions on Korean expressways and the detailed process of the proposed geocoding method. In Section 4, we compare the match rate of the final dataset to the results in California to evaluate the appropriateness of the method. In Section 5, we analyze the findings, discuss improvements, and provide suggestions for future research.

2. Literature Review

The geocoding methods that have been suggested in previous studies can be classified into four types: longitude/latitude coordinate geocoding, address geocoding, intersection and offset geocoding, and postmile or kilometer post geocoding. Fig. 1 shows examples of each of these types of information concerning the locations of collisions.

The recent development of Global Positioning System (GPS) technology allows the locations of collisions to be associated automatically with longitude and latitude coordinates (Sarasua *et al*., 2008). GPS data can therefore be imported directly into a GIS database. This would appear to be the most satisfactory geocoding method, but it is expected that it will take some time before the GPS-based accident investigation systems are widely used. Despite the technological benefits, it requires a large budget in order to put GPS receivers into all police enforcement vehicles, and accident investigation forms would have to be modified to incorporate this new information.

There are also other problematic aspects associated with current GPS devices. They do not function in blackout areas, such as inside tunnels. They may also occasionally deliver mistaken coordinates. Therefore, the accuracy of collision location depends upon how accurately the GPS device can correct for these errors (Miller and Karr, 1998). Furthermore, as the longitude and latitude coordinates are recorded in various forms, such as Degree-Minute-Second (DMS), Decimal Degree (DD), or State Plane (SP), there is also the issue of compatibility between the various forms of data transfer (Sarasua *et al*., 2008). Finally, there may also be a political opposition to the installation of GPS units into police enforcement vehicles due to privacy concerns.

The address geocoding method refers to the collision location by using the addresses of buildings or homes (or their postal codes) near the roadside where the collision occurred. In this case, collisions can be geocoded by using the 'Address Locator,' which is supplied by a GIS application such as ArcGIS (ESRI, 2008), or by using a customized tool that could be produced according to the needs of the researchers.

Yang *et al*. (2004) geocoded 5,000 addresses by using three widely available geocoding tools (ArcView, Automatch, and ZP4+Geolytics) to evaluate the advantages and disadvantages of each tool. In order to geocode pedestrian and bicycle collisions, Steiner *et al*. (2003) performed address geocoding by developing a customized ArcGIS geocoding application. Levine and Kim (1998) performed address geocoding by using vehicle crash data in Honolulu. The Google Maps application programming interface (API) can also be used to build a custom geocoding process.

However, due to variations in the descriptive accuracy of the original collision records, the success rate of matching via address geocoding can be poor in many cases. There are frequent errors when attempting to process each component of the descriptive location, such as the prefix, street name, or street type (Levine and Kim, 1998; Carreker and Bachman, 2000; Yang *et al*., 2004; Dutta *et al*, 2007; Bigham *et al*., 2009).

The intersection and offset geocoding method identifies the collision site by using intersecting street names and the offset distance and direction from the intersection. This provides an

Longitude and Latitude Coordinate		Longitude	Latitude			
		38.21329	-122.14265			
Address		Number	Primary	CITY	STATE	Zip code
		2614	DWIGHT WAY	BERKELEY	CA	94704
Intersection	w/o offset	Primary	Secondary	Intersection	Distance	Direction
		DWIGHT WAY	COLLEGE AVE	YES	0	-
	with offset	Primary	Secondary	Intersection	Distance	Direction
		DWIGHT WAY	COLLEGE AVE	NO	50	EAST
State Route with Postmile		State Highway	Route #	Postmile	Direction	
		YES	5	33.567	SOUTH	

Fig. 1. Example of Collision Location Information for 4 Coding Scenarios

output comparable to an address location and is useful when exact addresses are difficult to identify. Intersection and offset geocoding still faces the same difficulties in the descriptive accuracy of the record as exact addresses. Moreover, it also has other problems, such as dealing with the situation in which identical roads intersect in multiple locations (For further information, refer to Bigham *et al*. (2009) and Dutta *et al*. (2007)).

Dutta *et al*. (2007) developed an automated system for the geocoding of intersection and offset collision data in Wisconsin. They successfully mapped 78.5% of collision records with a 98% accuracy rate when comparing the results to the actual collision sites. However, despite the high accuracy rate for the location of the geocoded collisions, nearly 20% of the data were unable to be mapped due to the quality of the collision records. Steiner *et al*. (2003) automatically matched 1,291 crashes out of a total of 1,756 crashes (73.5%) using intersection geocoding and address geocoding methods. Levine and Kim (1998) obtained a match rate of 46.1% in the first step of these methods, and, after relaxing the street name, number, prefix (direction), and street type, the total match rate increased to 93.9%.

In the Statewide Integrated Traffic Records System (SWITRS), a collision database maintained by the California Highway Patrol (CHP) (2010), highway collision records specify the numbers or names of highways in the primary street field, the nearest crossing street in the secondary street field, and distances from the intersection as offset values. An intersection-based geocoding process could be used for highways just as it is for local roads, and the process is frequently used in this way, e.g., in Zhan *et al*. (2006). However, geocoding errors can be reduced and match success can be greatly improved by utilizing the linear referencing method for highway collisions.

Transportation agencies typically manage the establishments and landmarks around rest areas, ramps, traffic data collection devices, and traffic signs through an established linear referencing postmile/kilometer post system. The Korean expressway authority mandates the use of a postmile system for the collision report since the expressway is completely separated from local roads for toll collection purposes. Thus, all of the collision data of the expressway in Korea contains primarily the postmile information.

Geocoding via postmile referencing identifies a collision location by means of the road number and direction and postmile information. Recently, Bigham *et al*. (2009) geocoded fatal and severe injury collisions from 1997 to 2006 stored in SWITRS by categorizing datasets into local collisions and highway collisions. They applied the intersection geocoding method to local collisions and the postmile geocoding method to highway collisions. As a result, approximately 91% of a total of 142,007 fatal and severe injury collisions were successfully geocoded. The geocoding match rate on local roads was 86%, while the geocoding match rate of state highway collisions was as high as 99.8%. This higher success rate for state highway collisions can be attributed to the lower likelihood of original input error of the collision record and a greater ability to customize the street network. Therefore, it is desirable to develop a geocoding methodology using the postmile referencing for the Korea expressway system.

In addition to previous efforts in other countries, there is an attempt to geocode vehicle collisions on Korean roadways in a GIS framework. The traffic accident analysis system (TAAS) provided online by ‘Road Safety Authority’ offers locations and basic information of fatal collisions occurred on entire roads from 2007 to 2009 (http://taas.koroad.or.kr/service/gis/gis.jsp). The spatial analysis subsystem of the TAAS analyzes the characteristics of collision locations using GIS. However, the geocoding methods applied in the system cannot be verified due to the restriction of information revealed from the authority.

3. Methodology

3.1 Data Description

The street network and collision data were provided by the Korea Expressway Corporation. The 2007 street network included information on main sections of each expressway line, individual line segment lengths, and locations of reference points such as interchanges, toll gates, and local offices. A total of 14,840 major injury collision records were obtained from 2003 to 2007, an annual average of approximately 3,000 records. For 2008, property damage only and minor injury collisions were also included in the dataset, for a total of 10,039 in the single year. Table 1 shows the data sources in this study.

Each collision record is composed of more than 60 items, including information about the passengers, collision details, vehicles involved, road conditions, and other environmental factors. The location of the collision is recorded by the route name, direction, and postmile information. Additional reference items include the names of the route features (e.g., bridges, tunnels, mainlines, ramps, rest areas, and toll gates) of the collision location, which is insufficient to identify the exact location and only provides

Table 1. Data Sources

	Data	Description
GIS	Expressway Network	Geographic information on Korean expressways as of 2007 Recorded by 0.1 km segment Obtained from the Korea Expressway Corporation
	Reference Maps	Interchanges, junctions, toll gates and local offices for all expressways Obtained from the Korea Expressway Corporation
Accident	Collision database	Measured by 0.1 km (example: 56.7 km) From 2003 to 2007: fatal and severe-injury collisions only (14,840 collisions) 2008: All collision data including minor injury and property damage only (PDO) (10,039 collisions)

secondary location information.

The postmile geocoding method for Korean expressway is composed of four steps: creating routes, adding postmile markers (calibration points), calibrating routes, and geocoding collisions via linear referencing. ArcGIS 9.2 software and custom tools written in Visual Basic for Applications (VBA) were used for the entire process. ArcGIS VBA provides an integrated programming environment to build tools that complement the standard ArcGIS software. The following sections detail each of the processing steps.

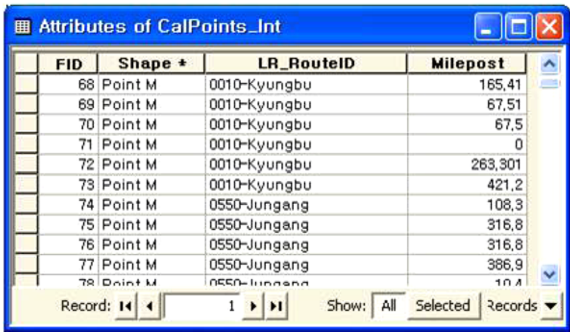
3.2 Creating Routes

The initial step of postmile geocoding is to build the continuous highway network. Because the existing routes in the base map from Korea Expressway Corporation are composed of 0.1 km segments for a management purpose, those expressway segments with the same route number have to be merged into a single line. We should have been able to complete this step by simply querying all segments by route number and merging them together, but due to errors in the expressway network, there were occasional problems in creating a single line. For example, some segments appeared to comprise a single line, but, under closer inspection, the data attributes showed incorrect route numbers or directions. In order to identify and correct these street network errors, a custom ArcGIS VBA tool was developed to aid the cleaning process.

After refining the street network, selected segments were merged into a single line, as shown in Fig. 2. The codes that indicated line number and line name, 0150 and Westcoast, for example, were combined to create a unique ID (0150-Westcoast) that is stored in the LR_RouteID field. With the cleaned and merged route segments, complete routes were finally built using the 'Create Routes' tool which assigns route IDs to each merged route.

3.3 Adding Postmile Markers

After the routes are created, postmile values must be assigned for known locations along the routes. The 'Feature Vertices to Points' tool in ArcGIS was used to automatically extract the start and end points of each 0.1-km segment that included the known postmile value. Other break points from connecting lines were also extracted to create more calibration points. These calibration points were given postmile values by referencing other known markers, such as interchanges or junctions. Fig. 3 shows an attribute table of postmile markers.



Attributes of CalPoints_Int

FID	Shape *	LR_RouteID	Milepost
68	Point M	0010-Kyungbu	165.41
69	Point M	0010-Kyungbu	67.51
70	Point M	0010-Kyungbu	67.5
71	Point M	0010-Kyungbu	0
72	Point M	0010-Kyungbu	263.301
73	Point M	0010-Kyungbu	421.2
74	Point M	0550-Jungang	108.3
75	Point M	0550-Jungang	316.8
76	Point M	0550-Jungang	316.8
77	Point M	0550-Jungang	386.9

Record: 1 Show: All Selected Records

Fig. 3. Example of Postmile Markers

3.4 Calibrating Routes

On Korean expressways, postmile values increase along each route from the westward for horizontal axes and from the southward for vertical axes. When using the tool, 'Create Routes,' coordinate priority was set at the lower left on the map, with the starting point of the line at 0 km and the ending point at the default value of the length predetermined by ArcGIS. However, it was necessary to re-establish postmiles of main segments, since errors occur in the street network and postmiles due to the reconstruction or improvement of expressways. The known postmile markers were input into the 'Calibrate Routes' tool of ArcGIS to calibrate the routes.

3.5 Geocoding Collisions

After calibrating all the routes, geocoding can be completed via linear referencing. For example, as shown in Fig. 4, if the starting point postmile is 0 km in a certain section of Expressway 15 and the closing postmile is 30, the positions of the other two points with postmile values can be interpolated between the starting point and closing point in proportion to the length of the whole section.

The collision records were processed to create a route ID with postmile values that match the expressway network format to prepare them for use in the ArcGIS tool, 'Make Route Event Layer.' If one designates a table for storing calibrated route layer and collision data, a field for storing route ID, and a field for

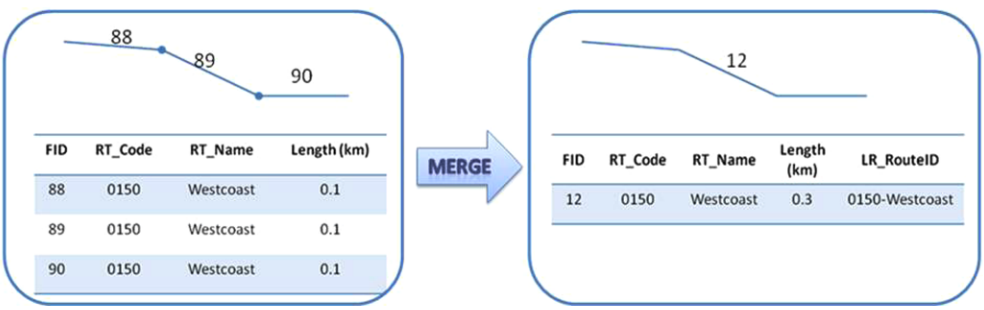


Fig. 2. Example of the 'Creating Routes' Process that Merges Segments into a Single Polyline

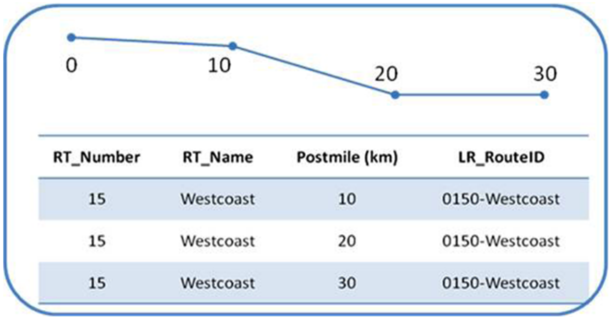


Fig. 4. Example of Finding Locations along an Expressway Using Linear Referencing

recording postmile values, collision points are automatically created by searching for the collision occurrence point. What's more, it is able to generate the field for predicting the occurrence of errors for each collision, so it is easy to correct the errors by searching for the collision location where the errors occurred after finishing the process. After inputting the collisions and the calibrated routes, the tool geocodes all collisions via linear referencing. Fig. 5 shows an example of collision data geocoded on the Southcoast Expressway. The collisions are shown as the points, and the text represents the postmile value of each collision.

3.6 Error Checking and Correcting

In order to ensure accurate geocoding results, significant efforts must be given to error-checking procedures. The methods of error checking can be divided into two categories. The first method is to review the error field created by the 'Make Route Event Layer' tool. There are three possible values: 'No Error,' 'Route Not Found,' and 'Route Measure Not Found.'

The value 'Route Not Found' occurs when the route on which the collision occurred does not exist in the calibrated routes. 'Route Measure Not Found' occurs when the postmile value of the collision location is beyond the scope of the postmile marker on the calibrated route.

The second method of error checking is visual inspection. It is easier to find errors with the naked eye on some routes on which there have been only a few collisions. On the other routes, it is possible to check the monotonic sequence of the postmile markers after labelling the postmile values of collisions on a map

Fig. 5. Example of Collision Data Overlaid on the Southcoast Expressway

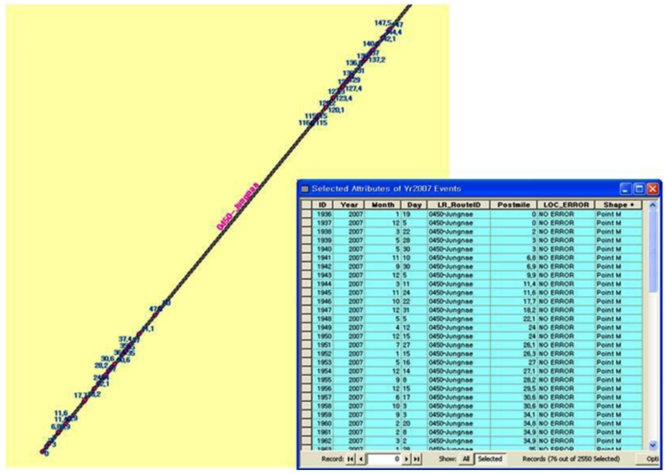


Fig. 6. Clustered 76 Collisions within 7-meter Segment

and traversing the successive routes. This method of visual inspection is only effective and manageable due to the relatively small total length of routes in the Korean expressway system. Nevertheless, it is very important, as emphasized by the error on the No. 45 Expressway shown in Fig. 6.

Fig. 6 shows a cluster of 76 collisions within a 7-meter distance from the starting point of a route (postmile 0 km). However, the actual postmiles of those collisions range from 0 km to 147.5 km and should be located accordingly. This problem is suspected to be due to a software error in ArcGIS, the solution of which has not identified yet. To work around this issue, additional calibration points were generated every 0.1 km, as shown in Fig. 7. After completing all error checking, the routes were re-calibrated, and the collisions were geocoded a final time. The entire process of the geocoding for Korean expressways is outlined in Fig. 8.

4. Geocoding Results

The results of geocoding by year from 2003 to 2008 are shown in Table 2. The results show that 24,854 out of 24,879 collisions

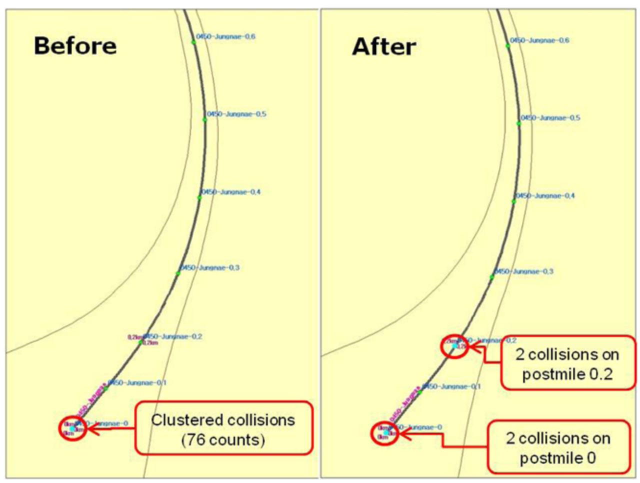


Fig. 7. Example of Correcting Clustered Errors

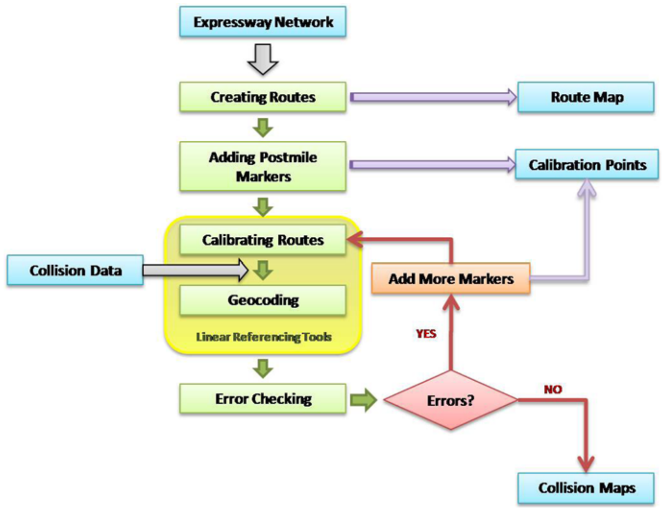


Fig. 8. Entire Geocoding Processes for Korean Expressways

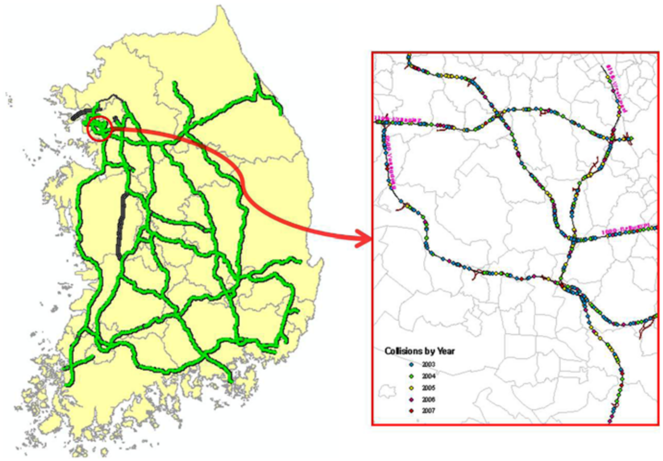


Fig. 9. Example of Geocoded Collisions from 2003 to 2007

were geocoded, for an overall match rate of 99.9%. There were 24 'Route Measure Not Found' errors, and there was one 'Route Not Found' error. 'Route Measure Not Found' errors were the result of invalid postmile values. For example, Line No. 1 has a total distance of 416 km, but postmiles of some collisions were actually recorded at 424 km, 424.5 km, and 425.6 km. Line No. 100 has a distance of 128 km, but a collision postmile was recorded at 327.1 km. The only 'Route Not Found' error occurred on the route that was constructed in late 2008. Since the base network was established as of 2007, the new route could not be created.

Table 3 compares the results of published geocoding methods. The results show this study produced much higher geocoded rate than other studies. Since address geocoding and intersection geocoding refer literal information such as prefix, street name, and street type, there might be frequent errors caused by errata, aliases or abbreviations. On the other hand, postmile geocoding can easily handle any incongruities since it refers numerical information such as route number and postmile. An important result of our research is also the evaluation of the applicability of postmile geocoding methods from different countries. The detailed processes and methods between the Korean expressways and state highways in California analyzed by Bigham *et al.* (2009) exhibited differences because the digital road networks of both regions were built based on different base networks which have dissimilar structures. Moreover, the street networks had a major fundamental difference in that California is focused on roadway maintenance and management while Korea is attempting to gradually grow its expressway infrastructure.

The California street networks had to account for postmile changes over time to avoid having a single location on the network with multiple postmile values. In Korea, the bigger challenge is keeping the street network database up to date with all the latest routes being constructed. However, the overall

Table 2. Geocoding Result on Korean Expressways

	2003	2004	2005	2006	2007	2008	Sum
Route Not Found	0	0	0	0	0	1	1
Route Measure Not Found	5	2	2	2	1	12	24
No Error	3,580	3,240	2,878	2,581	2,549	10,026	24,854
Total	3,585	3,242	2,880	2,583	2,550	10,039	24,879
Match rate	99.86%	99.94%	99.93%	99.92%	99.96%	99.87%	99.90%

Table 3. Comparison of the Results of Published Geocoding Methods

Author	Geocoding methods	Collisions	Road types	Crash types	% geocoded	Scale	Location
Levine & Kim (1998)	Address	15,975	all	all	94.4	County	Honolulu, HI
Steiner *et al*. (2003)	Address	1,756	All	Pedestrian	97.9*	County	Miami Dade, FL
Zhan *et al*. (2006)	Intersection & offset	59,247	Highway	All	95.6	County	Broward, FL
		35,531	Highway	All	97.9	County	Palm Beach, FL
Dutta *et al*. (2007)	Intersection & offset	4,351	Local roads	All	78.5	State	Wisconsin
Bigham *et al*. (2009)	Postmile	56,224	Highway	All	99.9	State	California
This study	Postmile	24,879	Freeway	All	99.9	State	Korea

*24.4% out of 1,756 collisions were manually and interactively geocoded.

framework of the methodology developed for the Korean expressways and state highways in California seemed similar and the methods for street network cleaning and error checking and the use of linear referencing to geocode collisions were easily transferable between Korea and California. Therefore, this study could provide a geocoding framework for researchers or practitioners in other countries that report collisions using postmile-based location coding.

5. Conclusions

This study established a methodology for geocoding collisions on Korean expressways with a high match rate. The expressway network built through this study can provide a foundation for quickly and accurately geocoding expressway collisions on a regular basis and can be easily updated when new routes are constructed. The geocoded database of expressway collisions will allow researchers to identify hot spots or justify road improvement projects and gives consideration to spatial factors that a traditional tabular analysis cannot. Collision maps can also be produced to aid traffic safety campaigns.

Our research also emphasizes the need for a highly accurate street network and correct location information for each collision record. The match rate only indicates that collision data were geocoded correctly on the expressways according to postmile values, but this cannot be regarded as an overall measure of accuracy. It is difficult to confirm whether the collision locations geocoded on the street network match the true location on the ground. The closer the street network represents the true locations and the more accurately collision postmile values are originally recorded, the higher the quality of the database will be.

For the years 2003 through 2008, 26,112 vehicle crashes caused 2,726 fatalities on expressways in Korea. While collisions on expressways make up only approximately 2% of the total of almost 1,317,000 vehicle crashes on all roads in Korea, the ratio of fatalities to crashes on expressways is just over 7%, which is much higher than the ratio for all roads in Korea. This indicates that the severity of expressway crashes is higher than that of crashes that occur on other types of roads. This increased severity results in exponentially increased economic and social costs Korean society must burden and emphasizes the need to reduce expressway crashes. The ability to quickly and accurately geocode expressway crashes is vital to achieving such a reduction and the methods and database developed for this study provides a solid foundation for future studies such as crash factor analysis, hotspot identification, and facility locations optimized for accident response activities.

Acknowledgements

This work was supported by National Research Foundation of Korea Grant funded by the Korean Government (2009-0075811). The generous support from the Engineering Research Institute of Seoul National University, Korea Expressway Corporation, and Safe Transportation Research & Education Center at U.C. Berkeley is also gratefully acknowledged. The opinions expressed in the paper, however, are solely of the authors and do not necessarily reflect the opinions of the respective agencies. The authos also thank the anonymous referees who reviewed an earlier version of this manuscript for their constructive and helpful comments.

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