Use of Remote Sensing to Identify Access Elements for Safety Analysis

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INTRODUCTION AND PROBLEM STATEMENT

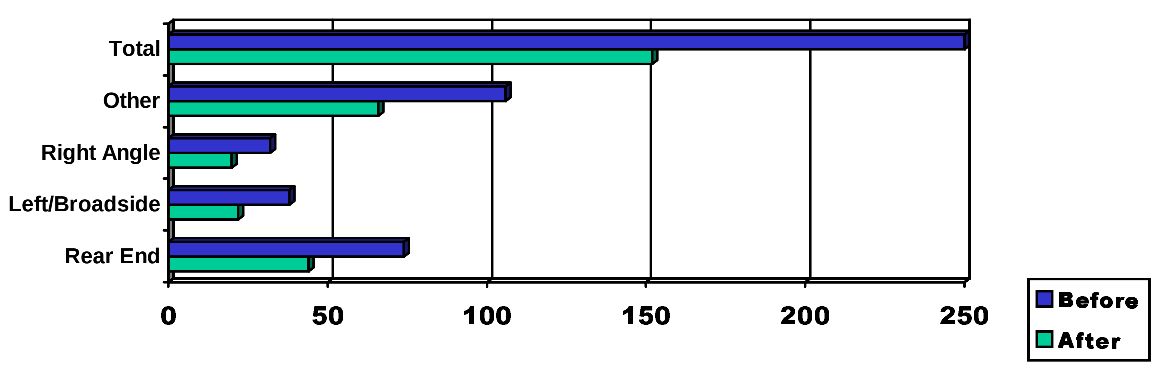
What is the Relevant Transportation Infrastructure Problem?

Crashes and increasing congestion resulting in delay, injury, loss of life and property damage continue to characterize the nation's highway system. These losses amount to hundreds of billions of dollars, tens of thousands of fatalities and over one million injuries annually (NHTSA).

The transportation system where these losses play out is immensely complex, and is comprised of diverse infrastructure, human actors, and institutions. One increasingly popular approach to partially addressing the problems listed above is access management.

Can we identify a significant treatment for the problem?

When access via driveways and minor public roads from arterial and collector roadways to land development is not effectively managed, the result is often increased accident rates, increased congestion, and increased delays for motorists. Research in Iowa and elsewhere has shown access management to be highly effective in increasing highway safety and improving traffic operations. Recent research in Iowa shows that access management projects led to an average 40 percent reduction in accident rates on case study routes in urban areas; these figures are consistent with previous research results in other states where reductions ranged from 18 to an impressive 77 percent (NCHRP 420). **Access management** projects are considerably less costly than building new facilities and can provide considerable increases in traffic capacity. The following graphic depicts typical crash rate reductions after application of access management strategies:



What are some of the barriers to effective and widespread implementation of access management strategies?

Widespread adoption of more aggressive access management often faces resistance from the local business community, especially if benefits are not perceived to directly enhance the local economy, or if treatments are developed with inadequate public participation. Other barriers to implementation include: limited ROW in built up areas, lack of ability to predict future problem areas, difficulty in applying models relating access control and safety due to **cost and availability of data**, and **lack of a systematic approach** (it is not always well know where in a state, improvements to access management would pay off best)

Can Remote Sensing help address some of the barriers to improved access management?

Remote sensing promises to **reduce cost of data collection** at large scales. A state the size of Iowa maintains over 100,000 miles of road, with the state Department of Transportation alone responsible for over 10,000 of the most densely traveled highways. Clearly at these magnitudes, in situ (field based) systematic data collection for roadway attributes is expensive. The objective of this project is to study the potential of remotely sensing techniques to reduce the cost of data collection required in access management programs, and **enable systematic identification of priority areas** for access management improvements.

BACKGROUND

Are models available to relate access infrastructure elements to crash or congestion prediction? Do the models require inputs that can be efficiently captured by remote sensing?

Several studies have resulted in models relating operational roadway characteristics (including indicators of level of access management) to safety measures. These studies were reviewed to identify the most appropriate model for meeting project objectives. While most crash prediction models include speed and traffic volume as explanatory variables, the “access management” models require data on driveway density and spacing, land use type, median and turn lane characteristics and intersection information. All of the access-related data inputs can be obtained from remotely sensed images of sufficient quality (see sections below for details).

Has remote sensing been used before to address the data needs of an access management program?

No published literature could be identified describing the application of remote sensing to access management data collection, per se. However, in a survey of selected state DOTs conducted as part of this project, several states were found to use aerial photographs to provide access data elements on a limited (corridor) basis (see table below). Other technologies identified in the survey included video and photo logging, extraction from as-built plans, GPS, traditional survey and other types of field observation. Several states indicated plans to develop comprehensive access management databases. Therefore, it seems timely to report on the applicability of remote sensing to the systematic development of such databases.

DOT	Data collection methods	Comments
Florida	Video logging and surveying	Driveway locations are collected if part of an improvement project or permit.
Kansas	GPS receivers	The access database is being developed. KDOT is investigating the option of utilizing aerial imagery for data validation and display.
South Dakota	Plan sheets from construction projects	Aerial photography is used extensively during planning and project development, but not as a data collection tool for access
Wisconsin	Photo logs and from driveway permits	Aerial photography is only used for route layout and design, but not as a data collection tool for access management.
Michigan	Video logs	Does not maintain information related to access on an annual basis.
Colorado	Video logs	Aerial imagery is used to identify access locations and circulation alternatives.
Oregon	Video logs and Manual Data collection	Aerial photography and satellite imagery are used for spatial data collection.
Minnesota	Field inventory, Video logs and from as built records	The methods mentioned are project specific. Currently there is no existing system to record access permits.
Iowa	Video logs and Field inventory	Aerial Photos are used to send the maintenance crews to exact locations

APPROACH AND RESULTS

The "Quantitative Approach"

What defines the quantitative approach and what are its objectives?

This project took two approaches to deriving information on level of access control from imagery. The first is referred to as the "quantitative" approach, where a model is calibrated to predict crash rates along segments of a corridor in Ames, Iowa. In this approach, explanatory variables related to access (see above) were enumerated by direct field observation and by manual interpretation and measurement from varying levels of aerial photography. The objective of the quantitative method is to determine the quality of imagery required to duplicate results of models whose data has been derived from field measurement. Of particular interest is the potential of satellite resolution (now 1 meter panchromatic, perhaps 0.5 meter in the near future) to provide the information on a statewide level. The ultimate objective of the modeling exercise is to identify priority areas for access improvement on a systematic basis.

Before investing in a modeling effort, alternative approaches to identifying priority areas for access improvement were considered. An example is the use of crash history alone for the identification.

Can crash history alone be used to rank segments in need of access improvement?

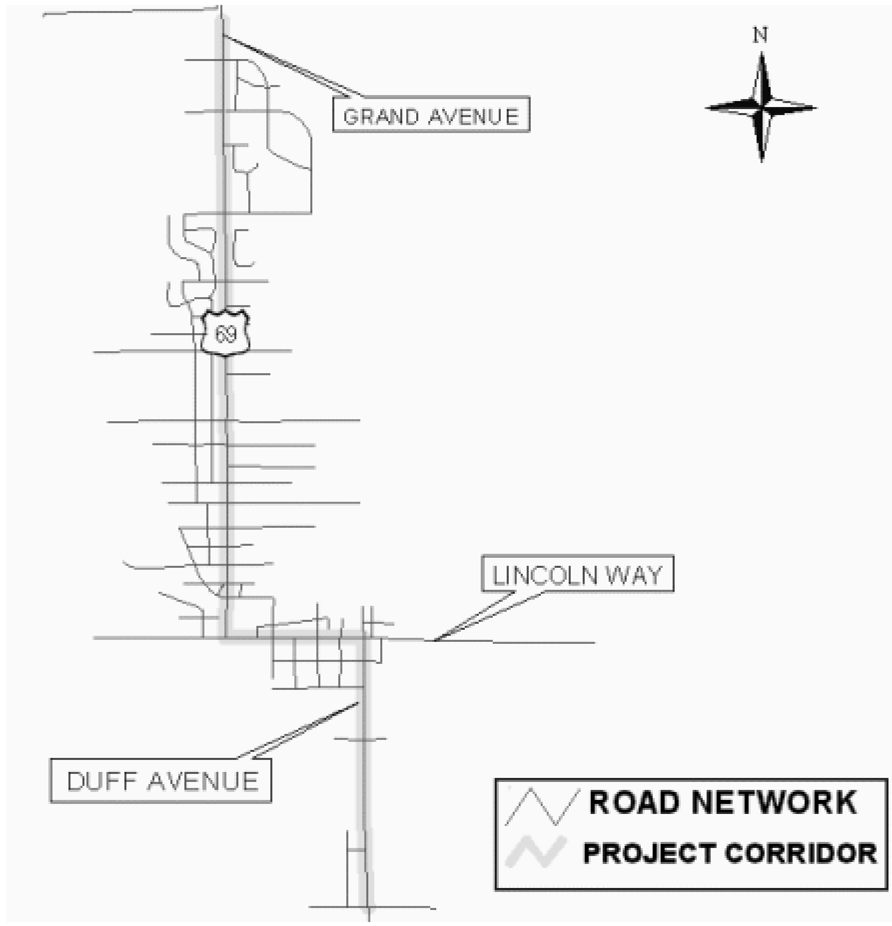
Yes, but this process has its limitations. All crashes are not access related. So, inherently, a simple ranking based on crash rate alone cannot produce a robust priority listing for access improvement. However, crash history in the corridor is useful as a calibration data set for a model (see below).

Then, could crash history for access-related crashes be used to identify areas in need of improvement?

Clearly. In fact, given a comprehensive, geospatial crash database, high priority segments can be identified to include those with an over-representation of non-signalized intersection and mid-block rear end and turning crashes. However, this is difficult if not impossible for network segments without such quality data. And, simply identifying high crash segments is insufficient to rank the segments for priority improvement. Further, transportation agencies are interested in the potential improvement afforded by improving the management of access – and a simple ranking based on crash history alone provides no such indication. A model is therefore warranted for both identification and prioritization of access management improvement segments.

Which corridor was selected for analysis?

The corridor selected for study is a 3.9-mile long section of US 69 in Ames, Iowa (see figure below). The corridor was broken down into 17 segments and is comprised of a variety of access levels (driveway densities, median types) and land uses (commercial and residential). Digital orthophotography was available for the corridor at six inch, two feet and one meter resolutions. The proximity of the corridor to the researchers facilitated field measurement. The figure below depicts the project corridor:



Which model is selected for the study corridor? How is it developed and calibrated? How well does it work?

Three models relating access characteristics and crash rates were identified (Sawalha, 2000, Brown 1999 and Bonneson 1997). For each, independent and dependent (crashes) variables were obtained from the Iowa DOT base record and ALAS databases. Field observation and measurement were made for access-related elements. For the model which worked best for the Ames 69 corridor (Sawalha's model developed for cities in British Columbia), parameters were calibrated using a technique suggested by Miller, et al (2000) using crashes during the 1996-1999 time period This time period corresponds to available imagery during which access geometry remained stable.

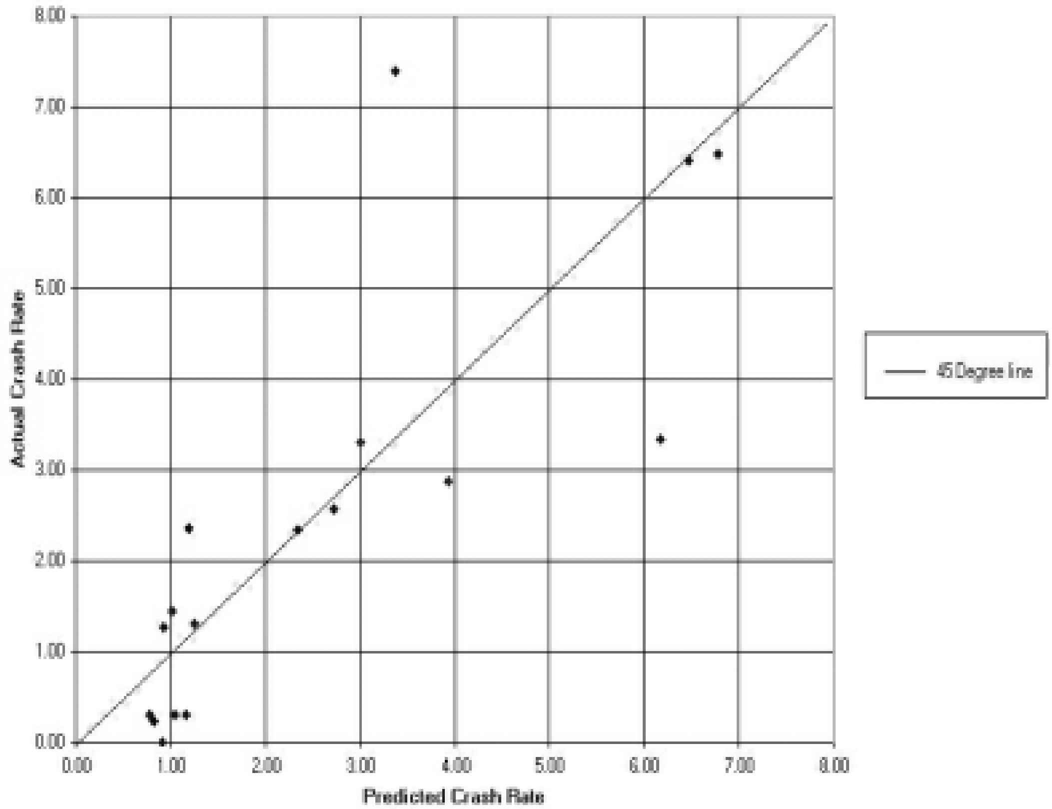
The calibrated model form is:

$$Crashes = 0.015 * L^{0.6051} * V^{0.6380} * \exp(0.12 * USD + 0.1458 * I_{UND} + 0.025 * DD * I_{BUS} + 0.0457 * NL)$$

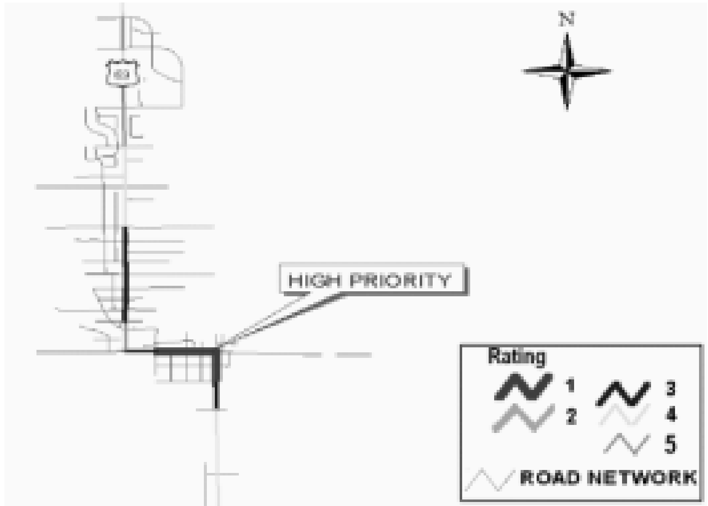
Where:

L = segment Length, kilometer
V = annual average daily traffic
USD = unsignalized intersection density, intersections per kilometer
DD = driveway density, driveways per kilometer
IUND = indicator variable for undivided median treatment, 1 if undivided; 0 otherwise
IBUS = indicator variable for business land use, 1 if business; 0 otherwise
NL = between signal number of lanes.

For the 17 segments of the corridor, the average number of crashes in a 4-year period is 21.4. The average model error for each segment is 6.4 crashes and the root mean squared error is 8.5. The figure below describes the model fit.



Approximately 900 crashes were observed during the study period. Results of the model were used to rank the 17 corridor segments with regard to need for access management improvement. The following figure illustrates how the model identifies priority areas for improvement of access, due to high mid block crash rate (Rating 1:high priority through rating 5:low priority, indicates order of a priority area/segment for access related improvements):



For the chosen model and study area, what data could be collected from imagery? How do the data derived from various sources and quality of imagery compare to field observed data?

All access data required for the model can be obtained from imagery, resulting in the **same relative ranking** of priority segments for access management improvement using either field or remotely sensed measurements. The following table clearly indicates that, for the three levels of imagery available, 6-inch resolution is required to provide reliable inputs to the quantitative model.

Access Related Data Elements		Detectability		
		6 inch	24 inch	1 meter
Driveways	Number	100%	>72%	>60%
	Land use	>99 %[1]	>99%[1]	*
Medians	Presence	100%	>50%	**
	Type	100%	>50%	**
Two way left turn Lanes	Presence	100%	0%	**
Intersections	Type[2]	100%	0%	0%
	Frequency	100%	100%	100%

[1]Based on number of driveways identified

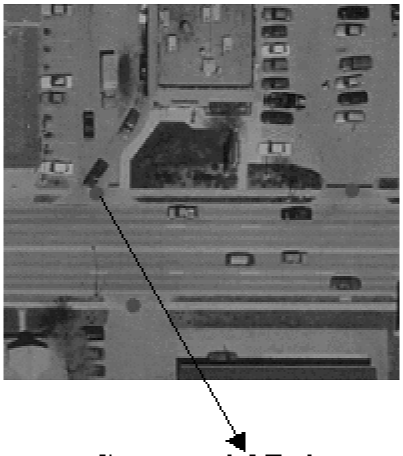
[2] Signalized or unsignalized

[3] Those identified were primarily raised medians with vegetation

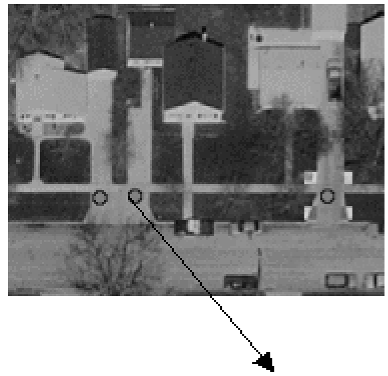
*Not feasible on a case-by-case basis, In most cases evaluation can only be made based on the surrounding area under consideration.

**Segments considered for analysis did not have medians or two-way left-turn lanes at the time the aerial photo was taken.

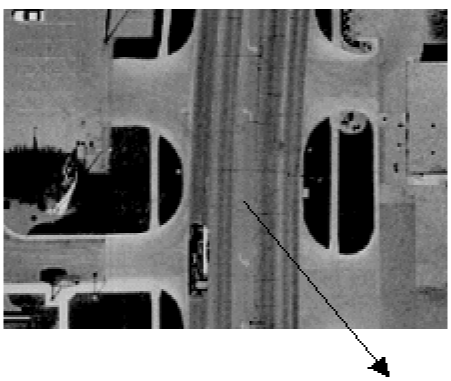
The following graphics depict the quality and use of the 6-inch imagery:



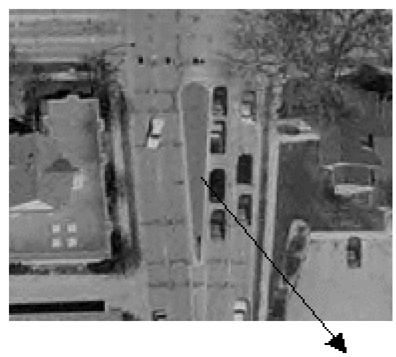
Commercial Driveway



Residential Driveway



TWTL



Raised Median

How do data collection costs compare between field and imagery?

If 6-inch imagery is available, the time required to obtain the access data for the corridor (3.9 miles) is 5 hours (reduced from 10 hours for field data collection). While the collection/reduction times may be reduced for image processing, it is likely that field data collection will be at least as expensive as indicated by this test (the measurements were made in the immediate vicinity of the research office). Care should be used in extrapolation of absolute costs, however, relative savings are apparent.

What are the limitations in the "quantitative approach"?

The method presented does not consider all access-related elements that can affect crash history. Further, remotely sensed, systematic data collection and processing, while less expensive than field data collection, **remains time consuming and expensive**. For example, if the State of Iowa wished to rank segments of State highway corridors within 5 miles of cities of 10,000 or more population, they would have to study some 1500 miles of state highway. Extrapolating the time required to collect and compile data for the four mile Ames corridor, one could expect to incur a time-only expense of some 6000 hours labor.

If the quantitative method is too costly or time consuming to enable statewide analysis, how can imagery be used? Can a quick, qualitative rating of a corridor explain essentially the same amount of variation?

A "Qualitative" approach

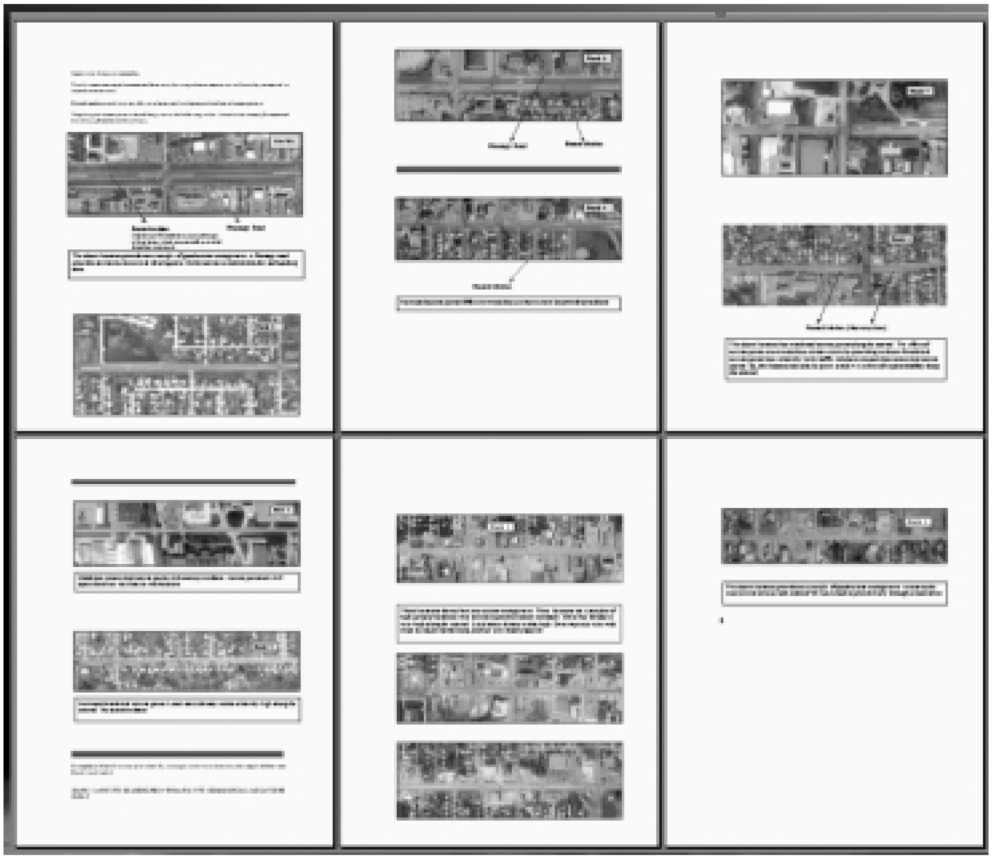
It is well known that trained human photo interpretation can have benefits over computational methods. For examples, humans can readily assess quality levels that a computer may take millions of operations to quantify, and some problems, e.g., n-p complete network problems cannot be absolutely solved. The researchers decided to test whether a quick, qualitative assessment of segment imagery could provide meaningful identification of priority corridors.

What should a "trained observer" look for?

Training materials were prepared for test observers. Five categories of access management quality (1 is worst and 5 is best) were defined and explained to the observers with text and sample imagery. The graphic below depicts some of the training materials.

What are the results of the qualitative assessment of the corridor? How do segment rankings derived from qualitative assessment compare to the quantitative model?

Eight observers were given brief training and asked to rate each corridor segment from 1 to 5. Quantitative model and actual, access-related crash history for each segment is also tabulated (rates were converted into 5 categories prior to tabulation of the qualitative assessments.) In most cases, the observer ratings can be seen to compare closely with model and actual ratings. The table below lists the results of the qualitative analysis.



Training Materials

SEG_NO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
RATING 1							b		a,e		e,f,h	a,c,d,e,f,h, M	a,c,d,e,f,h, M	a,d,g, M			
RATING 2							h	a,d,e,f	b,c		a,d, C	g	b,C	c,e,f,h,C	b,d,e,f	d,f,g	b,e
RATING 3					f	a,b,c, d,e,f,h	a,c,d,e,f,g, M	b,c,h, C,M	h, M		b,c,g, M	b,C	g	b	a,c,g, h, M	a,e	d,f,g
RATING 4	a,b,c, d,M		M	e,f,h	e,h,	g,M, C	g,C	g	d,f,g, C,	b,c,d,					C	c,h,C,M	a,h,C,M
RATING 5	e,f,g, h,C	a,b,c, d,e,f,g,h,C, M	a,b,c, d,e,f,g,h,C	a,b,c, d,h,C,M	a,b,c, d,g,C,M					a,d,f,g,h,M, C						b	c

M	Rating as Predicted by Model	a,b,c,d,e,f,g,h	Observers	C	Rating corresponding to actual access crash history

Results of Qualitative Ratings

Conclusions and Recommendations

How do the two methods compare? What's next?

In summary, several conclusions may be drawn about the two proposed approaches:

The quantitative model-based method is effective at the corridor level

1. The quantitative model produces same result (segment ranks) with field and remotely sensed imagery-based data collection and processing
2. Use of remotely sensed imagery can reduce costs of data collection by 50 percent or more when compared to field data collection methods (5 as opposed to 10 hours)
3. Savings can perhaps be enhanced by increasing the scale and automation of the procedure
4. 6" imagery is required, which is expensive, unless already available

Qualitative assessment is promising for larger studies

1. Cost savings are even greater for qualitative analysis (only 30 minutes are required to develop ratings for corridor of same magnitude)
2. Variability between observers exists, and must be assessed
3. For larger studies, there is potential to replace the human with an expert system or neural net (should be explored)

Other possible future tasks

1. Compare quality of available satellite imagery and impact of format (compression technologies) on the methods
2. Test more corridors to better extrapolate costs for systematic deployment
3. Refine estimates of benefits and costs of methods
4. Compare costs and accuracies of remote sensing with other methods, e.g., video log extraction

References

- *NCHRP 420*- Jerome Gluck, Herbert S. Levinson, and Vergil Stover. Impacts of Access Management Techniques, National Cooperative Highway Research Program, Report 420, Transportation Research Board, National Research Council, Washington, D.C., 1999.
- *Sawalha et al, 2000* - Ziad Sawalha, Tarek Sayed, Mavis Johnson. Factors Affecting The Safety of Urban Arterials. *Proceedings of the Transportation Research Board 79th Annual Meeting* (CD-ROM), Transportation Research Board, Washington, D.C., January 9-13, 2000.
- *Brown et al, 2000* - Henry C. Brown, Andrzej P. Tarko. The Effects of Access Control on Safety on Urban Arterial Streets. *Proceedings of the Transportation Research Board 78th Annual Meeting* (CD-ROM), Transportation Research Board, Washington, D.C., January 10-14, 1999
- *Bonneson et al, 1997* - James A. Bonneson and Patrick T. McCoy. Effect of Median Treatment on Urban Arterial Safety: An Accident prediction model, Transportation Research Board, Transportation Research Record 1581, Washington D.C., 1997.
- *Miller et al, 2000* – John S. Miller, Lester A. Hoel, Sangjun Kim, Kendall P. Drummond. Transferability of Models That Estimate Crashes as a Function of Access Management. *Proceedings of the Transportation Research Board 79th Annual Meeting* (CD-ROM), Transportation Research Board, Washington, D.C., January 9-13, 2000.