Development of Intersection Traffic Accident Risk Assessment Model

- Application of Micro-simulation Model with SSAM to Sungnam City -

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ABSTRACT

Traffic accidents at intersections in urban area are the most common and take a majority of the accident toll. Analysing and generating counter measures has been the major task for traffic safety officials and engineers. Without knowing the safety implications of the counter measures, the task normally concentrates on tackling accidents reflected in historic accident data. As more demand for traffic safety improvement emerges as local and national transport policy, more practical and site specific traffic accident risk assessment methodology is needed.

In the paper, a different approach of assessing the risk of intersection traffic accident using SSAM (Surrogate Safety Assessment Model, developed by FHWA, US) is applied to a real site in Sungnam, Korea. SSAM uses trajectory data from a micro-simulation model.

1. Introduction

Korean recorded 4th highest traffic accident toll among 29 OECD countries in 2007. Korean Government (The Ministry of Land, Transport and Maritime Affairs) amended the Traffic Safety Law in 2008 to take more responsibility in traffic safety policy and practice. The law requires local government to prepare "Traffic Safety Master Plan" for every 5 years.

The local mater plan includes traffic accident data analysis, black-spot treatment, education and publicity. KOTI (Korea Transport Institute) conducted "Traffic Safety Master Plan" for Sungnam City which is neighbouring Seoul as a part of 5-year traffic safety research and development project sponsored by the central government.

Traffic accidents at intersections in urban area are the most common and take a majority of the accident toll. Analysing and generating counter measures has been the major task for traffic safety officials and engineers. Without knowing the safety implications of the counter measures, the task normally concentrates on tackling accidents reflected in historic accident data. As more demand for traffic safety improvement emerges as local and national transport policy, more practical and site specific traffic accident risk assessment methodology is needed.

2. Review of Traffic Accident Risk Assessment Approach

There have been many different approaches to estimate potential traffic accident risk of intersections to support traffic safety officials and engineers including conflict analysis and accident prediction models and micro-simulation based method. Each approach has advantages and disadvantages.

1) Traffic Conflict Analysis (Ho 2004)

The concept of traffic conflict was introduced by Perkins and Harris in 1968 as any evasive action taken by a driver to avoid a collision. During the 1970's and 1980's, the concept has improved by including time-distance and severity dimensions to the measure of traffic conflicts. The traffic conflict is a measure of road user risk, taking into account driver behaviour, roadway condition and the traffic environment at the moment of exposure.

The severity and nature of traffic conflicts enables qualitative analysis and diagnose inappropriate traffic control, geometric design at intersections and road user behaviour. It can lead to identify site specific and accident type specific remedial measures. Where traffic accident records are not readily available, traffic conflict analysis provide very valuable information and quantifiable (although sometimes subjective) safety measures for safety evaluation purposes.

There are notable limitations of traffic conflict analysis. First, traffic conflicts are a record of successful evasive actions, which are not a substitute for good quality collision information. Second, the technique is limited primarily to intersections. Effective methods for observing and quantifying traffic conflicts along road segments through direct observation are unproven. Third, the cost for conducting traffic safety studies using the traffic conflict technique could be quite costly, because the current technique requires a total of 32 person-hours of survey time by trained observers at each intersection. Finally, the approach does not provide effectiveness evaluation of planned remedial measures.

2) Accident Prediction Model (APM)

TRL developed generalized linear regression model to relate accident frequency by category to functions of traffic and pedestrian flow, and a range of other junction variables. The model of four- arm junctions was developed on the basis of empirical data collected for 4 years (1979~1982) for 177 four-arm, single carriageway, signalized junctions on 30 mph limit roads in urban areas of UK

Three-arm accident prediction model was developed on the basis of TRL 135(Tylor, Hall and Chatterjee 1996) which studied 6 years (1985-1990) accident data for 221 three-arm junctions in urban areas . The model requires Traffic flow and Link Length data as minimum. To improve their accident forecasts, the user can input increasing levels of data for geometric data, including junction curvature, sighting distance, entry width.

The typical form of generalized linear model is as follows:

$$\log A = \log b_0\, x b_1\, x b_2 = \log b_0 + b_1 \log x_1 + b_2 \log x_2$$

where A = annual mean number of accidents

x_n = the average daily flow of vehicles,

b_n = the model coefficients

The advantage of APM is that it can be readily applied to four-arm and three-arm intersections in urban areas with minimum data. The one of the weak point of the APM is that the model is not transferable to other countries because it relies on the UK data. The model implicitly reflects road users' behavior which varies by areas.

3) Micro-simulation based Method.

Micro-simulation based safety analysis uses vehicle trajectories produced during the simulation. The trajectory data provide vehicle's position, speed and acceleration for user defined time resolution.

The Surrogate Safety Assessment Model (SSAM), a technique combining micro-simulation and automated conflict analysis, which analyzes the frequency and character of narrowly averted vehicle-to-vehicle collisions in traffic, to assess the safety of traffic facilities without waiting for a statistically above-normal number of crashes and injuries to actually occur.

Conflict studies traditionally utilize personnel trained to identify and record conflicts observed at an intersection. In this research, the SSAM software application was developed to automate conflict analysis by directly processing vehicle trajectory data. Researchers specified an open-standard, "universal" vehicle trajectory data format designed to provide the location and dimensions of each vehicle approximately every tenth of a second. It is hoped that video processing technology will, in the coming years, be capable of automatically extracting vehicle trajectory data adequate for SSAM processing. However, the trajectory file format is currently supported as an export option by four traffic micro-simulation models: VISSIM, AIMSUN, Paramics, and TEXAS.

To assess a traffic facility with SSAM, the facility is first modeled in one of the aforementioned simulation models and then simulated with desired traffic conditions (typically simulating several replications with different random number seeds). Each simulation run results in a corresponding trajectory file, referred to as a TRJ file corresponding to the .trj filename extension. Then, SSAM is used as a post-processor to analyze the batch of TRJ files. SSAM analyzes vehicle-to-vehicle interactions to identify conflict events and catalogs all events found. For each such event, SSAM also calculates several surrogate safety measures, including the following:

- Minimum time-to-collision (TTC).
- Minimum post-encroachment (PET).
- Initial deceleration rate (DR).
- Maximum deceleration rate (MaxD).
- Maximum speed (MaxS).
- Maximum speed differential (DeltaS).
- Classification as lane-change, rear-end, or path-crossing event type.
- Vehicle velocity change had the event proceeded to a crash (DeltaV)

SSAM provides a table of all conflicts identified in the batch of analyzed TRJ files, including file, time, location, vehicles identifications, and several measures of conflict severity.

SSAM provides a option to assess the safety of traffic facilities using popular micro-simulation software. This approach circumvents allows assessments of hypothetical designs and control alternatives, and is applicable to facilities where traditional, volume-based crash-prediction models (and norms) have not been established. Research is ongoing in this area, and as simulation models and video technology improve, this technique is expected to grow in use.

3. Application of SSAM to Sungnam City Test Site

1) Test Site

The test site of SSAM application is selected for a stretch of sections with 3 major intersections along the main arterial of Sungnam City. The road section has busy vehicular and pedestrian traffic due to the development of commercial area along the road side. The sections have 8~10 lanes and the legal speed limit is 70kph. The section and three intersections were selected as the top priority location for black-spot treatment.

The area was developed during 80s' without systematic urban planning and transportation planning consideration. The main arterial with 8~10 lane are crossed 2~4 lane minor arterials. The lack of hierarchical structure of the road network causes chronical traffic safety problem and accident. Sungnam City is known with its high traffic accident records amonst satellite cities around Seoul. The drawing and VISSIM simulation screen shot are shown below with accident diagram for each intersections and accident records for 3 years (2006~2008).

Figure 1 : Test Site

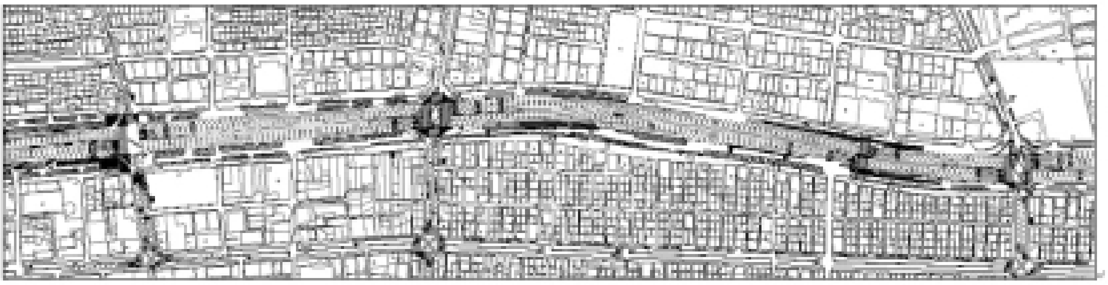
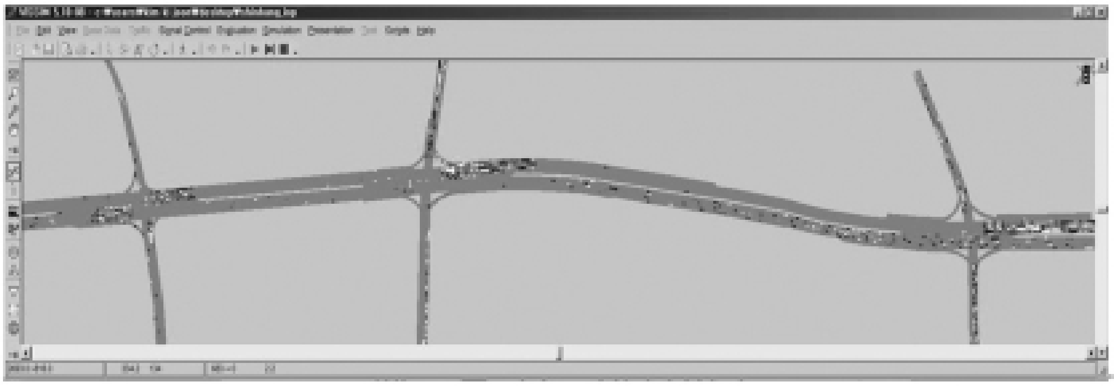
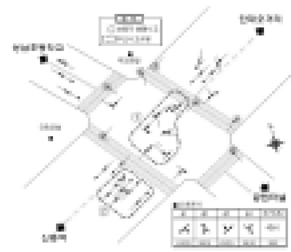


Figure 2 : VISSIM for Test Site



The collision diagrams, accident records, main accident causation and major remedial measures for each intersection are listed below. The accident causations of the three intersections show that traffic signal violation was the highest as a single cause. The high speed limit of 70kph induces speed violations and traffic signal violations. Speed control was the main remedial measure for the test site.

Table 1 : Test Site Accident Records and Remedial Measures

Soojin Station Intersection	Shinhung Intersection	Woori Bank Intersection
		
Total: 79 Casualties □Fatal : 0 □Serious Injury : 32 □Light Injury : 47	Total: 73 Casualties □Fatal : 1 □Serious Injury : 36 □Light Injury : 36	Total: 50 Accidents □Fatal : 0 □Serious Injury : 11 □Light Injury : 39
Main Accident Types □Ped. To Vehicle : 6 □Head-on collision : 1 □Head to tail collision : 13 □90 degree Collision : 8 □Collision by Lane Changing : 6	Main Accident Types □Ped. To Vehicle : 10 □Head-on collision : 8 □Head to tail collision : 5 □90 degree Collision : 17 □Collision by Lane Changing : 14	Main Accident Types □Ped. To Vehicle : 7 □Head-on collision : 2 □Head to tail collision : 11 □90 degree Collision : 7 □Collision by Lane Changing : 5
Accident time of day : □24~04 hour : 30% □14~20 hour : 33%	Accident time of day : □24~06 hour : 55% □16~18 hour : 12.5%	Accident time of day : □22~25 hour : 20% □04~06 hour : 16%
Major Accident Causation □Signal Violation : 32% □Unsafe Maneuvering : 46% □Speeding in the night in general	Major Accident Causation □Signal Violation : 38% □Unsafe Maneuvering : 47% □Speeding in the night in general	Major Accident Causation □Signal Violation : 28% □Unsafe Maneuvering : 49% □Speeding in the night in general
Major Remedial Measures □Signal Enforcement Camera □Speed Limit (70kph-> 60kph) □Longer Amber Time	Major Remedial Measures □Signal Enforcement Camera □Speed Limit (70kph-> 60kph) □Longer Amber Time □Ban U-turn □Realignment of E to N Right-turn	Major Remedial Measures □Signal Enforcement Camera □Speed Limit (70kph-> 60kph) □Longer Amber Time

2) SSAM application and results

The speed limit change from current 70kph to 60 kph was a major remedial measure for the test site. SSAM application was performed for peak hour and non peak hour with speed limit of 70kph and 60 kph. Trajectory data for 30 minutes simulation for each case was used for the SSAM analysis.

The result from non-peak hour case shows that mean TTC for 70 kph speed limit case was decreased for 60kph speed limit case. It can be deduced that lower speed case have shorter stopping distance than higher speed limit case. TTC can be shorter than higher speed limit case. DR decreased from -1.04 to -0.4. This means that driver apply breaking more smoothly under 60 kph speed limit than 70 kph speed limit. MaxD decreased from -1.46 to -0.81. The effect of lowering speed limit from 70 kph to 60 kph shows safer driving situation as expected.

Table 2 : SSAM Measure Results for non-peak period

Non-Peak	Speed Limit : 60kph				Speed Limit : 70kph			
SSAM Measure	Min	Max	Mean	Variance	Min	Max	Mean	Variance
TTC	0	1.5	0.36	0.35	0	1.5	0.46	0.4
PET	0	4.9	0.71	1.56	0	4.4	0.87	1.76
MaxS	0.8	17.51	8.81	15.08	1.48	25.35	9.55	23.93
DeltaS	0	17.51	5.9	19.34	0.02	20.73	5.8	17.06
DR	-7.82	3.43	-0.4	5.02	-7.73	3.29	-1.04	6.14
MaxD	-7.82	3.43	-0.81	7.04	-7.79	3.29	-1.46	7.71
MaxDeltaV	0	14.43	3.66	10.31	0.01	16.77	3.49	8.53

As speed limit changes, the total number of the conflicts and the distribution of conflict types are affected. The total number of conflicts increases as the speed limit is lowered. This increase is attributed by the increase of RearEnd conflict. This result contradicts the result of the SSAM measures above. This requires further investigation.

Table 3 : Conflict Types for non-peak period

Speed Limit	Total	Unclassified	Crossing	RearEnd	LaneChange
60kph	307	0	12	227	68
70kph	282	0	10	187	85

The result from peak hour case shows that mean TTC for 70 kph speed limit case was slightly decreased for 60kph speed limit case. DR increased from -0.09 to -0.22. MaxD increased from -0.54 to -0.69. It can be deduced that during peak-hours with severe congestion, speed limit has less meaning.

Table 4 : SSAM Measure Results for peak period

Peak	Speed Limit : 60kph				Speed Limit : 70kph			
SSAM Measure	Min	Max	Mean	Variance	Min	Max	Mean	Variance
TTC	0	1.5	0.3	0.31	0	1.5	0.28	0.29
PET	0	4.8	0.61	1.51	0	4.9	0.54	1.33
MaxS	0.02	17.85	6.89	11.41	0	20.21	7.21	15.55
DeltaS	0	15.16	3.9	9.42	0	19.5	4.16	11.88
DR	-7.9	3.5	-0.22	4.64	-7.7	3.4	-0.09	4.37
MaxD	-8.07	3.5	-0.69	6.81	-7.8	3.4	-0.54	6.57
MaxDeltaV	0	12.32	2.35	3.96	0	16.06	2.56	5.48

The total number of conflicts decreases as the speed limit is lowered from 989 to 913. This decrease is attributed by the decrease of RearEnd conflict. Crossing conflict increased from 12 to 32 and it requires further investigation.

Table 5 : Conflict Types for Peak period

Speed Limit	Total	Unclassified	Crossing	RearEnd	LaneChange
60kph	913	0	32	599	282
70kph	989	0	12	687	290

4. Concluding Remarks

The micro-simulation can be considered as a good representation of the traffic conditions in terms of speeds and flows. Nevertheless, this is not sufficient in the field of safety analysis. The individual behaviour of each vehicle must also correspond to reality.

Microscopic traffic simulators are based on the family of car-following, lane changing and gap acceptance models to model the vehicle's behaviour. In microscopic traffic simulation, incidents cannot occur as the basic modelling hypothesis in the underlying car-following models are designed to maintain a "safety to stop distance". Nevertheless, the knowledge of the vehicle's position, speed and acceleration (positive or negative) at any time should allow calculating a more relevant safety indicator than those deduced from macroscopic values. The usefulness of micro-simulation for safety analysis depends on the functionality of a micro-simulation model for replicating real world traffic flow and driver behavior, and calibration effort by uses. Also, the threshold value settings SSAM need to be further investigated for the future use.

References

Geoffrey Ho, Principle, Traffic Conflict Technique for Intersection Safety Analysis,

Road Safety Seminar organized by the Public Works Department of Malaysia and the Road Engineering Association of Malaysia, Kuala Lumpur, Malaysia, 29-30 March 2004.

Surrogate Safety Assessment Model and Validation: Final Report, FHWA-HRT-08-051

Surrogate Safety Assessment Model (SSAM): Software User Manual, FHWA-HRT-08-050

Traffic Safety Master Plan for Sungnam City, Sungnam City Government, 2009