COMPARISON OF MARYLAND'S PROCEDURE IN CRASH ANALYSIS WITH SAFETYANALYST'S AND INDIANA'S PROCEDURES

ESTIMATING ACCIDENT FREQUENCY		
This section is to compare the methods used in estimating accident frequencies at different stage of crash analysis. 3 different accident frequency estimations compared are as follows: i) *Current accident frequency* – Usually used in the screening of the high accident locations for representing the hazardousness of a location ii) *Future accident frequency* – Usually used in the benefit-cost analysis to provide a base for calculating accident reduction and hence the benefit of the project iii) *Accident frequency without improvements* – Usually used in the countermeasure evaluation for evaluating the effectiveness of the countermeasures in reducing accident frequency		
Maryland's procedure	***SafetyAnalyst procedure***	***Indiana's procedure***
Current accident frequency - Observed accident frequency is adopted	Current accident frequency - Empirical Bayes (EB) adjusted accident frequency - EB adjusted accident frequency is a weighted average between the observed frequency and that from the safety performance function (SPF) of similar	Current accident frequency - Observed accident frequency is adopted

	sites.	
Future accident frequency - Traffic volume is forecasted by using the linear regression results based on the volume data from the previous years'. - Accident frequency is assumed to be linearly related to the volume with the accident rate taken as the same in the before period.	Future accident frequency - Accident frequency from the SPF in the future are found by assuming a growth factor in the AADT - Accident frequency (EB adjusted) in the future period is found by assuming the same ratio of the EB adjusted frequency to the frequency from the SPF in both of the historic and future period,	Future accident frequency - Current accident frequency used in this evaluation is estimated by a function that combines the observed accident frequency and the frequency from the SPF (not the same as that adopted in the EB approach) - Future accident frequency is found by adjusting the above current accident frequency with the Exposure Adjustment Factor (EAF) - The EAF is non-linearly related to the change of risk exposure, which is in terms of traffic volume.
Accident frequency without improvements - Accident frequency is assumed to be linearly related to the after period volume and the accident rate taken as the same in the before period.	Accident frequency without improvements - Accident frequency in the future period is found by assuming the same ratio of the EB adjusted frequency to the frequency from the SPF in both of the historic and future period	Accident frequency without improvements - Similar estimation for the current accident frequency is adopted as that used in the future accident frequency - The accident frequency without

		improvement is found by non-linearly adjusting the above current accident frequency with the volume (exposure) ratio of the after period to the before period

Comments:

<u>Current accident frequency</u>

- *Using of observed accident frequency for screening (Maryland and Indiana)* – It has not considered the random fluctuation of the accident frequency. This oversee will cause the regression-to-mean errors (i.e. It will wrongly identify the less hazardous location or overestimate the effectiveness of the countermeasures in the later stages)

- *Using EB adjusted accident frequency (SafetyAnalyst)* – It could alleviate the regression-to-mean problem as the site accident frequency is adjusted by the average accident frequency of similar sites. But applying this method needs the SPF function, which requires extensive data collection for calibration, of the locations

<u>Future accident frequency</u>

- *Estimating future volume (Maryland, SafetyAnalyst and Indiana)* – Assuming a linearly varying traffic volume (Maryland) and a constant growth rate / increase in exposure (SafetyAnalyst and Indiana) is not realistic as they assume a constant increase / percentage change in traffic volumes over the future years. A more realistic forecasting could be done by fitting the historic annual volumes to a higher order curve to account for the possible increasing or diminishing increase in traffic volume.

- *Using of constant accident rate (Maryland)* – In Maryland's procedure, it is assumed that the accident frequency is linearly related to the traffic volume (exposure) and is assumed to be the same for the future period. It is not realistic as, depending on the characteristics of the location, accident rate change at different volume level. Thus, assuming a constant accident rate for all volume level could not precisely represent the actual situation. This issue is better addressed by the SafetyAnalyst, which used a non-linear SPF, and in the Indiana's procedure, which adopt a non-linear exposure adjustment factor in estimating the future accident frequency.

SCREENING HIGH ACCIDENT LOCATIONS

This section summarizes the procedures and indexes that are adopted to identify locations with abnormal high safety hazardous for further evaluations and considerations of safety improvement.

Maryland's procedure	***SafetyAnalyst procedure***	***Indiana's procedure***
Screening for section - The screening is completed by using the sliding scale method with fixed window length of 0.5 mile and in steps of 0.01 mile. - The locations are first screened by using the statewide average accident frequency. - The accident rate of the short-listed location is evaluated and compare with the upper control value from the Rate quality control method to form the finial list	Indexes - Potential safety improvements (PSI), which is defined as expected accident frequency or excess accident frequency, is used as the index for comparison - *Expected accident frequency* – EB adjusted accident frequency - *Excess accident frequency* – Different between the EB adjusted frequency and the value of the SPF from similar sites Procedures	Indexes - *Index of crash frequency* – A measure of how much the observed accident frequency is different (in terms of standard deviation) from the expected frequency found from the Safety Performance Function (SPF). - *Index of crash cost* – Modification of the index of crash frequency by taking into account the cost for each severity level. Procedures - Consideration of nine different categories,

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<td>- The final list is then ranked by the accident rate

- A three year combined data is used to form a separate list for the specific accident/collision type</td>
<td rowspan="2">- 4 types of screening and ranking procedures/criteria are considered

1) Locations with high PSI:
- For intersections and ramps, PSIs are evaluated at the spot for comparison and ranking
- For sections, sliding scale and peak searching method are adopted for identify the high PSI

2) Location with high proportion of specific accident
- Different accident type is found by multiplying the expected accident frequency (from the EB method) to the predefined distribution factors for different types of accident.

3) Detecting safety deterioration
- Safety deterioration is defined by i) a sudden, which in terms of percentage change, and ii) a steady, which measure by the rate of change, increase in PSI.</td>
<td rowspan="2">including different types of intersections and sections, for different locations

- Separate SPFs are considered for each location categories and severity levels

- All the nine categories of locations are ranked together by using the above two indexes.

- Seasonal variation correction factors are adopted to account for the different tendencies of having accident in different time of the year</td>
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<td><u>Screening for intersection</u>
- By using a county-wise average value and considering a Poisson distribution, the first cut-off value is defined

- Accident rates of the locations short-listed from the above steps are evaluated. Location with accident rate over 1 acc./MVE are considered as the final list.

- The final list is first ranked by using the accident rate. For the locations with accident rate, severity rate is evaluated used for rank.</td>
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	4) Screen for the high accident corridor - Locations (intersections, sections and ramp) within the same corridor are considered as a whole for comparison with other corridors.	

Comments:

- *Using of accident rate in screening process (Maryland)* – As the SPF, which estimates the number of accident at different volume level, is usually non-linear and convex in shape, using the accident rate as the screening criteria will tends to screen out the locations with low volume despite their actual hazardousness. Thus accident rate is not suitable for network screening and could be better substituted by using the frequency related indexes in SafetyAnalyst and Indiana's procedure.

- *Using statewide average accident rate (Maryland)* – This introduces bias in screening locations in different volume. It is because for the location with low traffic volume, their accident rates are usually lower as accident is directly proportion to the volume. Despite the actual hazardous of the location and the necessary of improvement, these locations with low volume will be more difficult to be short-listed by this procedure than those in the high volume area. As a result, this list will miss out some of the potential improvement locations in the low volume area and include some less important locations in the high volume areas

- *Using excess accident frequency (SafetyAnalyst and Indiana)* – Excess accident frequency in SafetyAnalyst and index of crash frequency in Indiana's procedure make use of the difference of the expected accident frequency of that location and the average accident frequency from the similar locations (SPF). The advantage of this method is that it screens the locations based on their deviation from the average accident frequency and gives a more precise comparison of hazardousness than the accident frequency, which will usually short-listed out the high volume locations due to their high exposure, alone. The main disadvantage of this method is SPFs for the location should be calibrated for comparison.

- *Using separate SPF for different severity level (Indiana)* – In Indiana's procedure, different SPFs are considered for each of the severity levels in each categories of location. This has an advantage over the consideration of distribution percentages of accident with different severity level in SafetyAnalyst that it allows for the different distribution of accident severity at different volume level. The main shortcoming is that it needs extensive work to develop and calibrate these SPFs.

- *Adopting seasonal variation (Indiana)* – In Indiana's procedure, different weights in contributing the annual accident is applied to different months of the year. Compare to Maryland's procedure, which accident frequency is evenly distributed all over the year, this method could indirectly account for the seasonal effects, like fog and snow, on the causing the accident and thus gives a more accurate estimation of accident frequency especially for the evaluation period is not a whole year.

- *Significant tests adopted in the screening process (SafetyAnalyst)* – In SafetyAnalyst, as the evaluation indexes depend on the SPFs, which have their own variances and means, the corresponding variances and means of these indexes could be found. Based on these parameters, the significance of these EB estimated frequencies could be found. This significance test gives the decision makers an extra information of examining the location in order for find out the real hazardous locations

- *Sliding scale method adopted in Maryland procedure (Maryland)* – In Maryland's procedure for section screening, sliding scale method with fixed window length is adopted. The deficiency of this method is that it could not screen out the location, or list of locations, which may have safety problems due to the corridor design, as the accident rate of each of the sites may not fulfill the screening criteria. In SafetyAnalyst, the deficiency is resolved by the corridor screening approach which considered the corridor as a whole for screening.

- *Consideration of the mixed ranking of different types of locations (Maryland, SafetyAnalyst and Indiana)* – In Maryland's procedure, which uses the accident rate, and SafetyAnalsyt, which users the PSI, it is difficult to fairly combine the list for the intersections/ramps and sections as the units of measuring accident rate (frequency) in these locations are different (e.g. no. of accident used in intersections/ramps

and no. accident/mile used in section). This issue is resolve in the Indiana's procedure as it measures the excess accident frequency in terms of standard deviation of which will normalize the accident frequency for a fair comparison between different location types. In using this approach, if the standard deviation is too large, that is the SPF function is not reliable, the effectiveness of the screening process will be seriously affected.		
BENEFIT-COST ANALYSIS		
The benefit-cost analysis is performed before any selection and implementation of improvement schemes. The aim of this analysis is to evaluate, monetarily, benefit and cost of the candidate improvement schemes to enhance the selection of financially feasible and beneficial improvement schemes by the decision makers		
Maryland's procedure	***SafetyAnalyst procedure***	***Indiana's procedure***
- Benefit of an improvement scheme is found by applying the accident reduction factors to the expected future accident frequency - Equivalent uniform annual cost (EUAC) and equivalent uniform annual benefit (EUAB), based on the interest rate and services life, over the service life is calculated based for further evaluation - Benefit-cost ratio, which based on the corresponding EUAB and EUAC, is used	- Accident modification factors are adopted for predicting the effect of the improvement schemes on accident frequencies - Both the EUAC and EUAB are used in the benefit-cost evaluation - Different criteria like cost effectiveness, benefit-cost ratio, net benefit and accident reduction could be used as the indexes for ranking the locations	- Accident modification factors are adopted for predicting the effect of the improvement schemes on accident frequency - Both the EUAC and EUAB, with additional consideration on inflation, are used in the benefit-cost evaluation - Based on the EUAC and EUAB, the benefit/cost ratio and net benefit is evaluated for ranking the improvement schemes

as the evaluation index.	- An optimization problem could also be adopted for finding the set of improvement schemes that maximized the total net benefit within the available budget.	

Comments:

- *Evaluation indexes (Maryland, SafetyAnalyst and Indiana)* – Similar evaluation indexes like benefit-cost ration and cost effectiveness is used based in the EUAC and EUAB evaluated

- *Use of benefit-cost ratio (Maryland)* – If benefit-cost ratio is used as the sole criterion for project selection, it may have a defect of choosing the improvement schemes with marginal reduction in accident frequency as for their low implementation cost. More comprehensive consideration could be made by introducing other indexes like net benefit.

- *Use of the optimization model (SafetyAnalyst)* – Instead of choosing the countermeasures with highest net benefits (or any other evaluation index considered) to implement, the optimization model in the SafetyAnalyst analytically considered the trade-off between the benefits and cost of the countermeasures such that choice of improvement schemes will maximize the total net benefit under any given budget. Currently, only net benefit is considered, but other indexes (like percentage decrease in accident frequency or the decrease in the proportion of fatal/severe accident) should also be considered as the objectives for optimization.

- *Consideration of inflation rate (Indiana)* – In the calculation of the EUCA and EUCB, both of the Maryland's procedure and SafetyAnalyst only consider the interest rate , which is the rate that the money gain by the capital for each year, but not the inflation rate. Inflation rate is a measure used to estimate the change of buying power of each monetary value at different time (i.e. the buying power of $100 now is different from that of 20 years later if there is an inflation or deflation). If the inflation rate is neglected, the actual value of the future cost (or benefit) will be under-estimated (if deflation occurs) or over-estimated (if inflation occurs). As a result the EUCA and EUCB calculated could not truly reflects the actual situation (especially when comparing with improvement schemes with or without operation and savage cost or for the scheme with relative long services life, say 20 years)

COUNTERMEASURE EVALUATION

Countermeasure evaluation is performed after the implementation of the improvement plans when there is sufficient after period traffic and accident data for supporting the evaluation. The aim of this evaluation is to find out the actual effectiveness of the chosen countermeasures in reducing accident frequencies and to check whether other unexpected safety issues are induced by these countermeasures.

Maryland's procedure	***SafetyAnalyst procedure***	***Indiana's procedure***
Significance testing - By considering the Poisson distribution, accident frequencies are checked whether they are significantly reduced after the implementation of improvement schemes Effectiveness measuring indexes - Change of accident frequencies in different collision types are considered and tested for significance. - Cost effectiveness and benefit-cost ratio are used to evaluate the effectiveness of the improvement schemes	Significance testing, - The significance of the reduction is evaluated by considering i) the ratio of the EB adjusted accident frequencies with the improvement schemes to that without the schemes, and; ii) the corresponding variance of this ratio Effectiveness measuring indexes - Percentage change in accident frequencies for different severity levels are used as the major mean of evaluating the effectiveness of the countermeasures	Significance testing, - By considering the Negative binomial distribution, accident frequencies are checked whether they are significantly reduced after the implementation of improvement schemes Effectiveness measuring indexes - Standard cost/benefit evaluations like cost effectiveness and benefit-cost ratio are adopted

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<tr><td></td><td>- Benefit-cost ratios will also be evaluated for comparison</td><td></td></tr>
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- Significant tests (Maryland and Indiana) – In Maryland’s procedure the Poisson distribution is assumed for the significance test while the negative binomial distribution is adopted in Indiana’s procedure. In reality, as the negative binomial distribution could more accurately reflects the usually over-dispersed accident data, the using of negative binomial distribution gives a more precise test of significance of the safety improvements. Thus, if the over-dispersion parameter is available, which is come with the SPF for the similar sites, the negative binomial gives a more accurate result than the Poisson distribution</td></tr>
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