Identifying Roadway Sections With "Critical" Large Truck Accident Rates*

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INTRODUCTION

A considerable amount of transportation-related data exists at the national and state levels which may be of assistance in the evaluation and modification of routing and risk assessment models currently utilized by the Department of Energy's Transportation Technology Center at Sandia National Laboratories. This information, including the Federally-supported Fatal Accident Reporting System - FARS (U.S. Department of Transportation 1984), National Accident Sampling System - NASS (U.S. Department of Transportation 1987), and Highway Performance Monitoring System - HPMS (Kittell 1984), can be used to evaluate both existing and proposed model applications as well as to formulate strategies for future model and associated data base improvements.

Current efforts at the national level appear to be focusing on attempts to create a National Safety Information System. This system would merge existing information relating to highway accident, highway inventory (such as geometric data), and traffic volume data which is currently maintained in separate computer files. Any model applications involving accident rates would thus have to access this combined file since such calculations require roadway section length and volume information as well as data on accident occurrences. State traffic record systems also appear to be moving toward this consolidated approach, although routine use of such special-purpose files appears to be a few years away (Wolff 1989).

Existing truck accident analyses at the state-wide level, then, must rely on highway accident and roadway inventory data bases residing in separate, often incompatible, computer files. The purpose of this paper is to present an overview of efforts currently underway to analyze roadway geometric data and accident rate information from a variety of sources to develop a relationship between these data and accident probability indicators for specific roadway segments, and to develop a computerized methodology to determine parameters of interest. This methodology will then be included on the TRANSNET system of models and data bases where the accident probability value may be used to perform analyses in codes such as StateGEN/StateNET or RADTRAN.

A technique for merging accident record and roadway inventory files and for utilizing the combined data set to identify sections of a rural Interstate highway system that have unusually high accident rates involving large truck vehicles is presented here as a prototype of the accident probability methodology. This statistical technique, known as the rate/quality control method, involves calculating a "critical rate" for each roadway section. This critical rate is a function of the traffic volume on the section, the overall systemwide accident rate, and a desired level of statistical significance. Observed accident rates on each section are then compared to the section's critical

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**A United States Department of Energy Facility rate and sections are ranked according to their "criticality," that is, the numerical difference between their observed and "critical" rates.

With ongoing data collection efforts and concomitant improvements in data quality, particularly involving large truck accident rates, the technique may ultimately have application to the formulation of routing decisions regarding the transport of radioactive or other hazardous materials and in the evaluation of routing alternatives.

Subsequent sections of the paper describe in detail the rate/quality control technique and its application to a state-wide, rural Interstate highway network, develop the computer code for merging the accident and inventory files, and describe the selection of critical roadway sections. Conclusions and recommendations for further work follow.

THE RATE/QUALITY CONTROL METHOD

The rate/quality control method of traffic accident analysis has been borrowed from comparable techniques employed in industrial quality control (Zegeer 1982). The procedure is statistically-based and defines those spots or sections where the observed accident rates are higher than would be expected due to normal variations in the data. The technique requires both the observed accident rate for the section and a calculated critical rate. The critical rate is determined by first calculating an average accident rate (RA) for all sections of roadway (including those containing no accidents) for the particular highway system under consideration. This calculation is as follows:

$$RA = (A \times 1{,}000{,}000) / (ADT \times L \times N)$$

where:

RA = average accident rate on the section per million vehicle-miles of travel,
A = total number of accidents on the section for the time period in question,
ADT = average daily traffic on the section,
L = section length in miles, and
N = number of days in the time period.

A statistical test, based on the commonly accepted assumption that accidents follow a Poisson distribution, is necessary to calculate each section's critical rate. A level of significance of 0.05 is commonly used (the analyst can be 95% confident that the section accident rate, based on the number of accidents and some measure of vehicle-miles of travel, would not exceed the critical rate). For a significance level of 0.05, the value of the statistical factor (K) is 1.645. Values of the factor for other levels of significance may be found in any standard statistical reference. Using a larger value, for example, will both decrease the number of critical locations identified by the technique and increase the number of segments which are not identified as critical. The procedure also requires an estimate of the amount of travel on each individual section; this parameter is usually expressed in millions of vehicle-miles.

Given the above information, the critical rate may be calculated as:

$$RC = RA + K\sqrt{RA/M} + 0.5/M$$

where:

RC = the calculated critical rate on the section (per million vehicle- miles),
RA = the average accident rate for all sections of roadway,
K = the statistical factor for a given level of significance, and
M = travel on the section in millions of vehicle-miles (mvm).

The equation shows that the critical accident rate for a section of roadway is inversely related to the amount of travel on the roadway. This relationship is shown in Figure 1, which compares the critical accident rate for a one mile section of roadway with the ADT on that section. The horizontal axis in the figure may also be interpreted as the daily vehicle-miles of travel on a section with a length of other than one mile. Observed accident rates above the curvilinear function shown in the figure are critical and thus deserve further study. A ranking of all sections by the difference between the observed rate on a section and its critical rate provides a means for prioritizing such sections.

A simple example may be used to demonstrate the approach. Assume that a 3.0 mile section of rural Interstate roadway has an ADT of 1,000 vehicles per day. Assuming constant volume, the total vehicle-miles of travel during a typical three year analysis period is:

M = (1,000 vpd x 365 days/yr x 3 years x 3.0 miles) / 1,000,000 = 3.285 mvm

If the average rural Interstate system accident rate is 0.187 large truck accidents per million vehicle-miles, and the chosen level of statistical significance is 0.05, the critical rate for the section is calculated as:

$$RC = 0.187 + 1.645\sqrt{0.187/3.285} + 0.5/3.285 = 0.731 \text{ large truck acc./mvm}$$

Thus, for any section with this amount of travel, there are 95 chances in 100 that, if the observed accident rate exceeds the critical rate, the section may require further study. If a total of 6 large truck accidents occurred on this section during a three year period, for instance, the actual accident rate (RS) is:

RS = (6 accidents x 1,000,000)/3,285,000 = 1.83 accidents/mvm

The actual rate (1.83 accidents/mvm) clearly exceeds the critical rate (0.731 accidents/mvm). The difference between the actual and the critical rates (1.099 accidents/mvm) is the criticality of the section; because the criticality is positive, the site is a logical candidate for further study.

APPLYING THE RATE/QUALITY CONTROL TECHNIQUE

The development of a list of critical large truck accident sections on New Mexico's rural (non-urban) Interstate system is used as an example of the approach and may be viewed as consisting of a number of distinct steps:

1. Calculate systemwide accident rates for some period of time (3 years minimum) for New Mexico's rural Interstate system,

2. Define what constitutes an individual roadway section and calculate the total vehicle-miles of travel on that section,

3. Select a level of significance and calculate the critical accident rate for each defined individual section,

4. Calculate an accident rate on each individual section, compare it to the critical rate for that section, and rank sections by their criticality.

The interrelationships among these steps are illustrated in Figure 2 which indicates that the procedure for identifying critical sections first requires the examination of two computerized files --

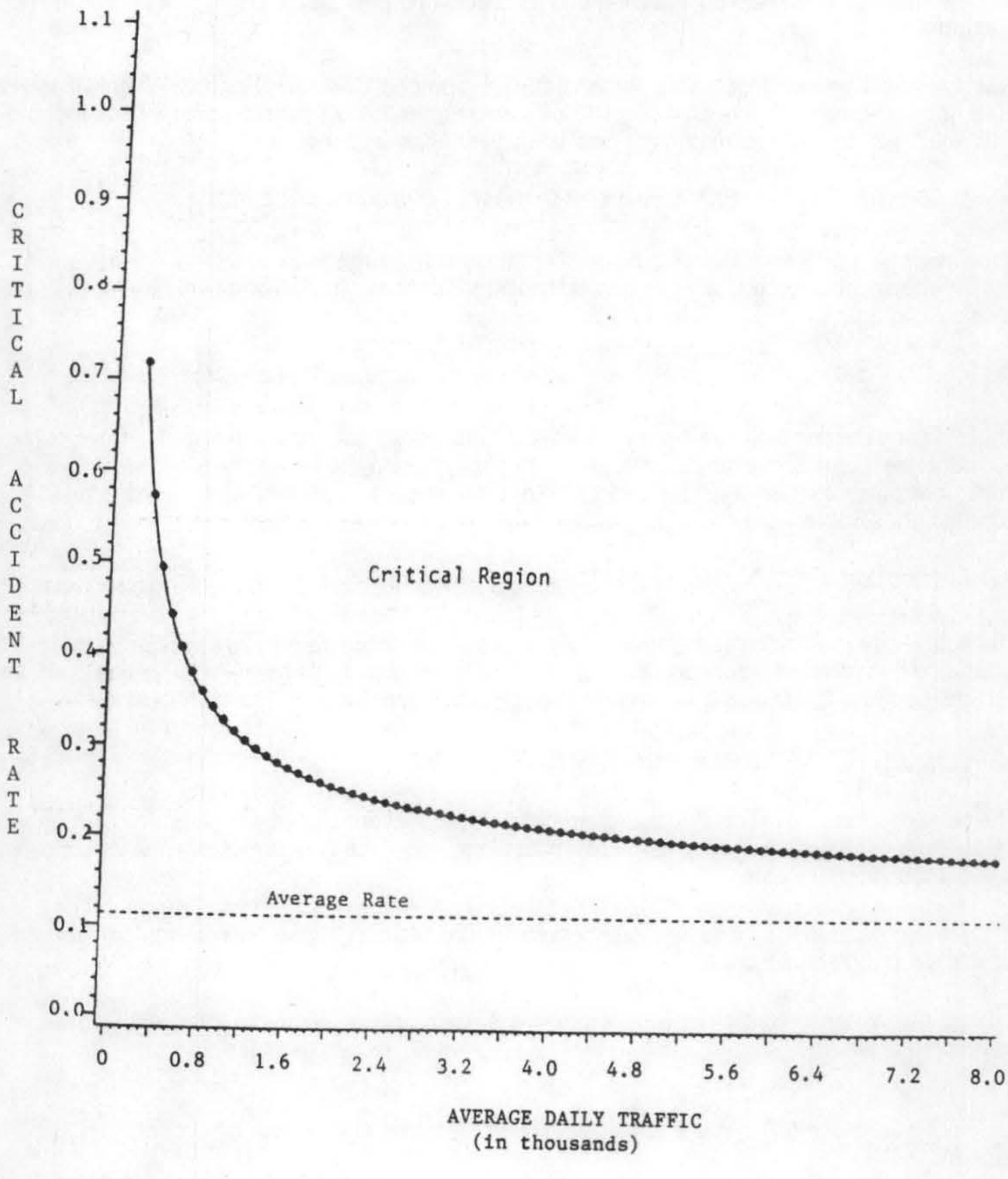

Figure 1.
Critical Accident Rate vs Volume

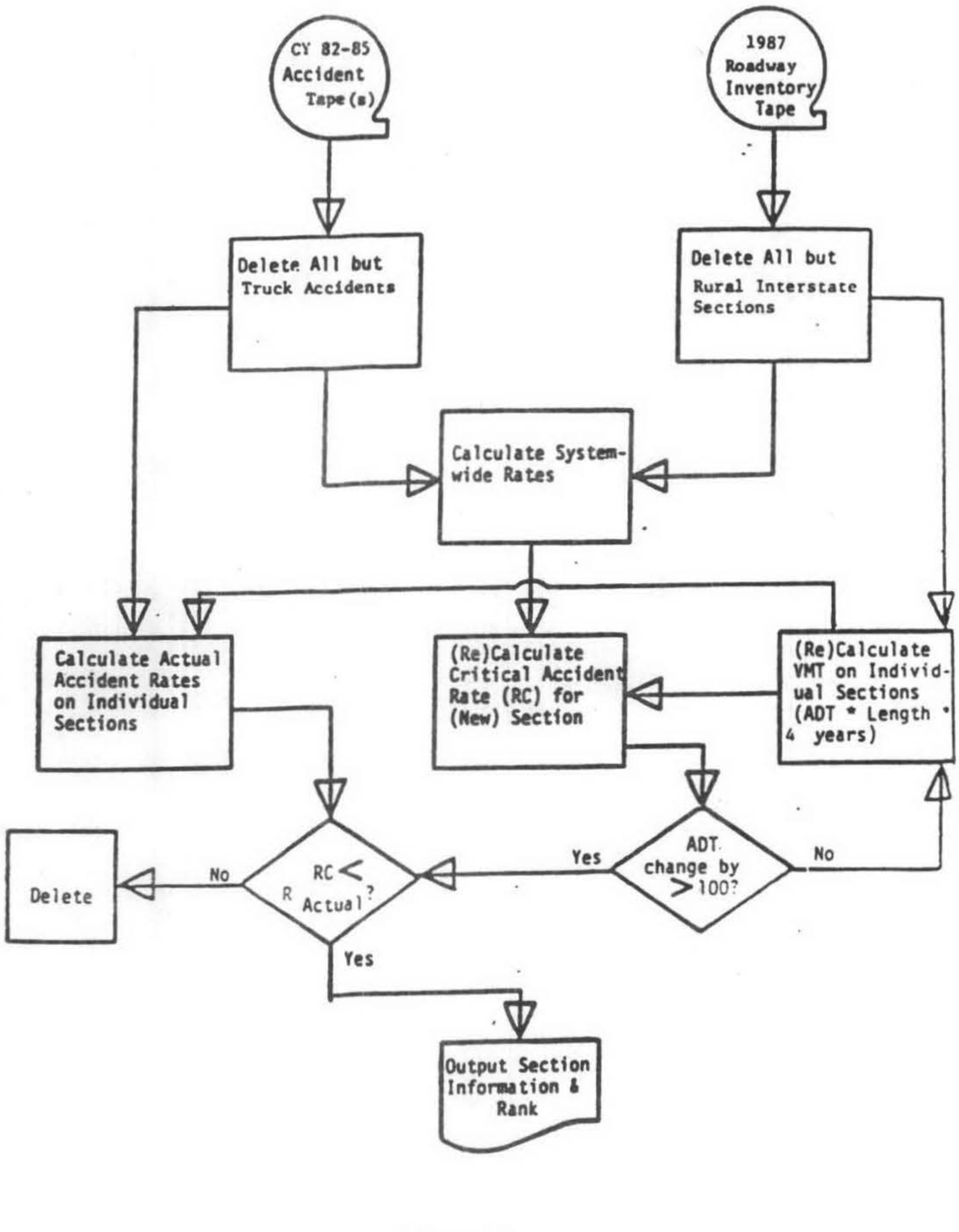

Figure 2.
Calculation of Critical Interstate Large Truck Accident Rates

TABLE 1

CRITICAL TRUCK ACCIDENT SECTIONS ON NM INTERSTATES
ARRANGED BY DECREASING CRITICALITY

ROUTE	COUNTY	FROM	TO	NACC	TRAVEL	RATE	CR_RATE	CRITICAL
256	COLFAX	455.899	457.060	7	4856	0.9872	0.3954	*
401	MCKINLEY	30.503	33.767	33	45554	0.4962	0.1912	*
405	GUADALUPE	273.602	275.014	9	11162	0.5523	0.2842	*
401	MCKINLEY	26.197	30.503	38	60510	0.4301	0.1803	*
401	MCKINLEY	34.000	36.767	23	37078	0.4249	0.2003	*
401	MCKINLEY	36.767	37.199	5	5846	0.5858	0.3649	*
405	GUADALUPE	243.500	256.436	54	107769	0.3432	0.1629	*
401	MCKINLEY	47.062	50.183	22	41509	0.3630	0.1952	*
404	TORRANCE	222.665	232.314	43	92245	0.3193	0.1670	*
401	MCKINLEY	0.000	4.166	20	40773	0.3360	0.1960	*
405	GUADALUPE	277.023	277.615	4	5577	0.4912	0.3723	*
255	SAN MIGUEL	309.006	322.118	22	49383	0.3051	0.1879	*
405	GUADALUPE	299.627	303.317	16	35166	0.3116	0.2029	*
401	MCKINLEY	40.000	47.062	36	94810	0.2601	0.1663	*
405	GUADALUPE	267.900	272.997	19	45935	0.2833	0.1908	*
404	TORRANCE	206.876	218.064	43	118151	0.2493	0.1606	*
102	LUNA	85.509	101.950	51	148314	0.2355	0.1555	*
402	CIBOLA	114.898	117.366	14	33888	0.2830	0.2047	*
102	DONA ANA	134.637	135.110	3	4100	0.5011	0.4269	*
405	GUADALUPE	256.436	267.900	35	101788	0.2355	0.1644	*
404	TORRANCE	218.064	222.665	17	44413	0.2622	0.1922	*
401	MCKINLEY	23.054	26.197	14	35214	0.2723	0.2028	*
102	DONA ANA	101.950	123.933	62	201142	0.2111	0.1495	*
256	COLFAX	416.367	420.636	6	13315	0.3087	0.2676	*
404	GUADALUPE	232.314	239.395	20	63007	0.2174	0.1788	*
101	HIDALGO	6.176	11.300	14	41320	0.2321	0.1954	*
256	MORA	366.100	389.496	18	56367	0.2187	0.1828	*
406	QUAY	322.000	329.221	21	68135	0.2111	0.1762	*
401	MCKINLEY	37.199	40.000	13	38150	0.2334	0.1990	*
102	LUNA	68.470	81.224	28	99045	0.1936	0.1651	*
101	GRANT	24.565	49.970	47	183846	0.1751	0.1511	*
402	CIBOLA	126.824	131.200	17	56625	0.2056	0.1827	*
405	GUADALUPE	285.182	291.289	18	60814	0.2027	0.1801	*
404	TORRANCE	187.200	190.871	15	49206	0.2088	0.1880	*
405	GUADALUPE	272.997	273.602	3	5086	0.4040	0.3874	*
401	MCKINLEY	4.166	9.042	14	47843	0.2004	0.1892	*
402	CIBOLA	89.729	96.520	23	89573	0.1759	0.1678	*
402	CIBOLA	96.520	102.200	19	71772	0.1813	0.1745	*
402	CIBOLA	85.402	89.729	16	58651	0.1868	0.1814	*
401	MCKINLEY	16.334	20.814	13	45866	0.1941	0.1909	*

a four calendar-year file (1982-1985) containing data from all 7,089 large truck accidents in the State and the 1987 Roadway Inventory tape containing, among other things, traffic volume and section length information. Both files (as well as the code written to merge the files and calculate the critical sections) are written in SAS (for Statistical Analysis System), a broad-based computer software system for information storage and retrieval and statistical analysis (SAS User's Guide: Basics 1982; SAS User's Guide: Statistics 1982). Examination of the accident data identified 1,666 locatable large truck accidents on the State's rural Interstate system for the time period in question.

The Roadway Inventory files yielded 580 arbitrarily-defined segments of rural Interstate roadway, with lengths ranging from just over 20 feet to slightly under 11.5 miles. Combining information from the accident records with segment length and ADT information from the Inventory enabled the calculation of a systemwide accident rate (RA) for the entire rural Interstate system. This rate is 0.1152 large truck accidents per million vehicle-miles of travel (one large truck accident per 8.7 million vehicle-miles of travel). Variations from the system-wide rate are apparent when individual highways are examined. The entire length of I-10, for example, has both high numbers of observed large truck accidents and accident rates per million vehicle-miles considerably higher than average. Similarly, two sections of I-40, one beginning at the Arizona border and the other at the Guadalupe County line, have both high numbers and rates. Interstate 25, on the other hand, has, with one exception, rates which are considerably below average.

Use of the systemwide accident rate results in the critical rate calculation for individual sections for a significance level of 0.05 as follows:

$$RC = 0.1152 + 0.5583\sqrt{1/M} + 0.5/M$$

The process illustrated in Figure 2 identifies 580 unique rural Interstate segments in the Roadway Inventory. Vehicle-miles of travel on each segment is calculated by multiplying the ADT for the segment, the segment length in miles, and the number of days in the 4-year analysis period (1460). In order to reduce the total number of segments to a more manageable group and to eliminate very short segments, the program compares ADTs of adjacent segments; if they differ by less than 100 vehicles per day (VPD), the program combines the two and determines a revised VMT. This procedure is repeated until ADTs differ by more than 100 VPD; at this time the combined information is retained and a section is defined.

This process identifies 251 sections. From locational information - coded mileposts - in the two computerized files, the number of large truck accidents occurring on the sections is determined and an accident rate for the section is calculated. This information is then sorted by route number and milepost, ranked by criticality, and printed.

A total of 40 rural New Mexico Interstate sections is identified in the example as being critical. Of the 40 identified sections, only 4 are on I-25 and 6 on I-10; the remaining 30 sections are on I-40. These sections are shown in Table 1. Information on the critical sections includes the administrative route number, the county, the beginning and ending mileposts of the section , the number of large truck accidents on the section during the four year 1982-1985 analysis period , the daily vehicle-miles of travel, and the actual and critical accident rates for the section. Such a listing may be employed by a routing analyst to identify sections of a roadway system with high large truck accident rates.

SUMMARY AND CONCLUSIONS

The objective of this paper has been to develop a procedure for identifying portions of a highway system experiencing high accident rates involving large trucks. A computer code has been written to merge accident and roadway inventory information and, employing a technique borrowed from industrial quality control, to rank roadway sections based on a comparison of the actual accident rate on the section and a statistically-determined critical rate. This information may be valuable in the analysis of routing alternatives.

While the technique can rank roadway sections by the accident rate on the section, a number of enhancements may be appropriate in order to improve the process. Better estimates of truck, rather than total vehicle travel, as well as other data base improvements, need to be addressed further. This enhancement also involves more control over traffic volume counts in general. Efforts are now underway at the state level to address both of these issues (New Mexico State Traffic Monitoring Standards 1988).

A second area of concern is the fact that the locational information in the Roadway Inventory is superior to that contained in the Accident Record System. One incorrectly coded accident could thus have a dramatic impact on the identification of a critical location, particularly on short sections with low ADTs. This may be less of a problem on Interstate facilities where reporting is handled by State Police.

A final area of interest is the continual updating of the Accident Record System data base. Recent changes have included a variable designating hazardous material involvement in the Accident file as well as details relating to placarding, cargo manifests, and hazardous material spills in the Detail level file.

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