

INFLUENCE OF ROAD CHARACTERISTICS ON TRAFFIC SAFETY

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Paper Number 07- 0064

ABSTRACT

The objective of this traffic safety investigation was to find critical road sections using Post- and Pre-accident analysis approaches. The Post-accident approach analyzes the effect of road geometric characteristics on accident rate. The study was based on accident and road maintenance data in Western Sweden. A total of 2912 accidents from 2000 to 2005 on 1615 km median-separated roads was collected and combined with road characteristics (Speed, carriageway width, AADT, vertical and horizontal alignments, superelevation) for analysis (Post-accident approach).

The statistical analysis showed that road characteristics have great effect on accident ratio (AR defined as number of accidents per million vehicle kilometer

- AR and injury severity increase with increasing speed limit.
- A carriageway of 5,8m has the lowest AR, with a distinct tendency for AR to decrease with lane widths greater than 5.8m.
- AR decreases with increasing radii of curve for right and left-turn curves. Left-turn curves have higher AR than right-turn.
- Road sections with left-turn curve radii of less than 100m have highest AR; they are four times as high as those with curve radii greater than 500m and twice as high as right-turn curve radii less than 100m.
- The lowest AR were observed for superelevations of 3-4%. AR increases when superelevations increase or decrease from 3-4%.
- AR on downgrades is higher than on upgrades.

In a Pre-accident approach the IST-Checklist method 2005 has been used. A tool based on human behavior that assesses a place or a road section's inclination to trigger accidents. The purpose was to investigate

applicability of IST on Swedish roads and then using it to find critical road sections. The results show that the method doesn't function as expected for blind tests made on Swedish road sections which showed weak correlation between real accidents and IST results.

The investigation approach and results are useful input for designing future active safety systems such as ABS and ESP that are sensitive to the road characteristics.

INTRODUCTION

Background

Road safety engineers are faced with the challenge of addressing safety issues within the three major traffic safety pillars: human, vehicle, and infrastructure. All three aspects must be part of a traffic safety plan and dealt with subject to budget limitations. Consequently, the cost efficiency of systems and countermeasures are decisive factor for policy making.

The European Commission (EC) funded RANKERS project (Ranking for European Road Safety) in the 6th Framework Research Program. The ambitious objective of this project is to develop scientifically-researched guidelines enabling optimal decision-making by road authorities in their efforts to promote safer roads and eradicate dangerous road sections. It was also designed to gain new knowledge by performing research and empirical studies of the road's interaction with the driver and their vehicle in order to identify optimal road recommendations and predict their impact on safety. The main output of the project will include an index used for assessing and monitoring road safety and a comprehensive catalogue of road infrastructure safety

recommendations ranked according to their cost-effectiveness [1].

This road safety analysis is a part of RANKERS project. Its main purpose is to find areas with clusters of problems (black spots) and dangerous road sections by defining a methodology to better understand road characteristics that leads to traffic accidents.

Studying and analyzing accidents data on selected roads is the starting point to determine black spots. Finding road characteristics where most of the accidents occurred, a Post-accident approach is the method which has been used in this paper to find correlations between road geometry parameters and accident rate.

Another strategy to find black spots is from a human behavior perspective studying and analyzing traffic situations to evaluate how safe a road is to drive on. This pre-accident approach uses a tool called the IST-Checklist method 2005. The IST method has been developed by Intelligent System Transfer in Potsdam. It has already been applicable and successfully applied on parts of the German road network [2].

The idea behind applying the IST checklist is to examine its functionality on Swedish road network and apply it afterwards on the selected roads. The IST checklist is applied on a place or a road section to analyze its inclination to trigger accidents from human behavior knowledge. The evaluation is based on a checklist where the results suggests treatment actions. Another idea behind the IST checklist is to improve and gain new skills- and guidelines for new constructions to avoid accidents in the future [3].

Objective

The objective of this study was to use post- and pre-accident approaches to find critical road sections. A Post-accident approach was to evaluate the effect of the main road geometry characteristics on accidents, in other words to quantify and test possible changes in accident rate on roads where their geometrical parameters change. To achieve this aim the existing data stored by road administration, police and hospitals have been used.

In Pre-accident approach the IST-Checklist method 2005 has been used as a tool used to analyse traffic safety on the basis of human factors. It analyses the road environment's inclination to trigger traffic accidents. Evaluation of the IST checklist was to

assess if the tool can be used on the Swedish road network in the future.

Limitation

Accident data was limited to personal injury accidents, while the road types of were limited to median-separated public roads in the western region of Sweden. The period of investigation was 6 years (2000-2005). Only the effects of the following parameters on accident rate have been addressed: speed, curvature, carriageway width, super elevation, and road grade.

From human behavior perspective the IST checklist 2005 method, has been tested only on two road sections of a total length of 5.6 km to evaluate and blind test their safety levels according to IST.

METHODOLOGY

Two different parallel methods have been used to achieve the mentioned objectives of this study, detailed methodology for each of them is explained separately in the following sections.

Post-Accident Approach

Existing accident and maintenance databases have been used to find correlations between road geometry characteristics and accidents. The maintenance data was from the Swedish Road Administration (SRA) is stored in a database called PMS (Pavement Management System) while accidents reported by police and hospitals collected in databases OLY and STRADA.

After choosing an area and a period of investigation the analysis method was carried out in four phases: 1- Collecting accident data, 2- Collecting road characteristics data, 3- Locating accidents and combining them with the road data, 4- Analyzing collected-combined data statistically to locate and identify black spots.

For evaluation of the effects of the road parameters, simple and multiple regression techniques were used, in which accident data was the dependant variable while geometry parameters were independent variables. For the results to be considered significant, final regression equations were to have regression coefficient, R^2 , that was significant at the 0.05 level for simple regression analyses. In multiple regression analyses, each of the independent

variables included in the equation had to have R^2 that was significantly different from 0 at the 0.05 level.

The Region of Investigation was the Western region of Sweden which has been chosen for the investigation due to weather variations which are comparable with other regions in Sweden. Another reason is the amount of traffic on the selected public roads is 36% of the total Swedish traffic flow.

Accident Data have been collected from two national accident databases, OLY (Accident Database) and STRADA (Swedish Traffic Accident Data Acquisition). Both databases contain only personal injury accidents. OLY contains accidents based on police reports until the end of year 2002. After that OLY has been replaced by STRADA which is based on reports from police and hospitals to minimize accident reporting loss. Through the hospital report acquires a better picture of the injury severity [4] is also achieved. The accidents known by both the polis and hospitals are matched in the database.

In 2000-2005, a total of 3599 road traffic accidents involving personal injury (including fatal, severe and slight injuries) were reported to the databases. Of these, 690 accidents have been excluded due missing road data for accident location, or non-criteria accidents.

For every reported accident the following information has been recorded in both the OLY and STRADA databases: accident ID, date, type, place and description, number of killed, severe and light injuries, weekday, time, road condition (wet, dry or snow) and lighting conditions.

Locating accidents are different in both databases. OLY uses start and end nodes and the accident locations are given as a distance from the start node to the accident location. STRADA is a GIS-based system (Geographical Information System) which permits mapping tools to locate accidents during both the registering and analyzing of data.

Road Data for the specific types of roads has been targeted to fulfill RANKERS project guidelines, which is separated-median public roads. The total length of the selected roads in 2005 was 810 km including 480 km motorway, 47 km 2+1 semi-motorway, 15 km semi-motorway and 147 km 4-laneway.

Sources used to collect road data were the PMS (Pavement Management System) and NVDB (National Road Database) databases, which are owned and maintained by the Swedish Road Administration (SRA).

The PMS (Pavement Management System)

contains data for the road and its surface condition. Its main function is to supply information about road surface and road geometry which can be used to identify optimum maintenance strategies (repairs and rehabilitation activities). The system is to support decisions concerning when, where, and what countermeasures should be taken on paved roads. However it must be emphasized that the purpose of the system is not explicitly used for safety analyses.

Annual road measurements are collected with a special survey vehicle, Laser Road Surface Tester (Laser RST). The Laser RST scans and measures the transverse profile of the road at varying speeds up to 90 km/h with 17 laser sensors. They are placed on a support beam at the front of the test vehicle. The collected data is processed and verified according to purpose-designed statistical and mathematical procedures.

The parameters collected/calculated from the Laser – RST sensors are wheel rut, IRI (International Roughness Index), super elevation, curvature, texture and grade. They are stored for every 20 m road length. The database is completed with other road traffic information such as speed limit and AADT (Annually Average Daily Traffic).

The PMS database is constructed with links which they have unique ID. The links are assembled together by joints (knot point). Every joint represents a junction or an interchange.

To take advantage of the database for traffic safety purposes, measurements at accident locations have been extracted and recorded together with the accidents for further analysis. The chosen parameters are speed limit, carriageway width, curvature, super elevation and grade.

The NVDB (National Road Database)

consists of road links connected to each other by joints (in the same way as PMS). Furthermore the links are divided into several sections. These sections are components of NVDB and every section has a unique ID. The nodes have identical names in NVDB and PMS which enable data interchange between them.

NVDB contains a huge amount of data which describes roads and traffic regulations. Presently just a small part of this data is of interest for accident analysis. Surface layer material and carriageway width are the only parameters in NVDB which describe roadway.

Using NVDB in this study was limited to the speed limit for OLY accidents and road opening day to make sure that the accidents have occurred on the desired type of roads.

Another use of NVDB is for boundary marking desired roads at STRADA then picking up

corresponding accidents. Other interested attributes in NVDB are also available at PMS in more detail such as road type.

Combining Accident- Road Data has been done manually. Accidents during 2000-2002 were collected from OLY manually, while the rest (2003-2005) were gathered from STRADA with help of ArcGIS software. The collected accidents had to be completed by road data from PMS and NVDB for analysis. This part was the most time consuming in the method. The procedure began with selecting relevant accidents; deciding associated roads with driving direction and afterwards collecting road information for the accident locations. The road information had to be measured the same year when the accident occurred so that effect of road parameters on accidents could be studied.

After removing accidents that hadn't occurred on relevant roads and those that occurred before the road's opening day, a total of 1057 accident have been collected from OLY (OLY were in paper document form), while 1855 accident were collected from STRADA.

The next step was to provide and connect road data, from PMS and NVDB databases, to the data extracted and collected from OLY and STRADA. The step has been implemented manually [8].

Connecting accidents to road data can be done also by using a automated method called ArcMap handle [9]. ArcMap handle had been applied to some collected accidents in order to compare it with the manual method. It was found that the automated method is faster and more effective than the manual method, but it is less accurate. About 15% of accidents ended up being reported for the wrong direction of the road while 87 accidents (3.7%) were connected to wrong roads.

Several Parameters were used in the subsequent analysis; orientations of parameters are referenced to the vehicle's original travel direction. Relevant road data were:-

- Speed limit (50,70,90 or 110) km/h
- Road type (motorway, expressway, expressway 2+1, normal 2+1 and 4-lanesroad)
- Annual Average Daily Traffic (AADT which provided by SRA for years 2002 and 2005, interpolation has been used for other years)
- Carriageway width, W, [m] (Classified to four groups, $W \leq 5.8$ m, $5.8 < W \leq 7.5$ m, $8 < W \leq 11.7$ m and $W \geq 12$ m.

- Curvature, classified to left and right- curves and analyzed in terms of radius of curve [m]

$$Radius\ of\ curve\ [m] = \frac{10000}{Curvature} \quad (1)$$

Right and left curves divided according to length of the radius: greater than 1500, 1000, 500, 200 and 100 m.

- Grade divided into up and down-grades, where they subdivided to: 0 – 2%, 2 – 4% and 4 – 6%.
- Super elevation classified to negative and positive-super elevations, while each of them divided to: 0 – 1.5%, 1.5 – 2.5%, 2.5 – 3%, 3 – 4%, 4 – 5% and $\geq 5\%$.

The assignment of accident location by the police at the time of accident was not always precise. Errors of up to a couple of hundred meters can occur in accident localization. But accident localization can be considered as normal distributed around the real accident location. [5]. Because of this, an average value of around 200 m (100 m before and 100 m after the 20 m section where the accident occurred) has been taken for the mentioned parameters.

In the rest of sections where no accidents occurred, a mean value has been taken for the road parameters. In this case length of sections varies between 150 and 400, which is length of the NVDB sections.

Pre-Accident Approach (IST-Checklist)

The IST-Checklist Method was different from post-accident approach and was based on conflict and consequences. The IST-Checklist, pre-accident approach, takes the human behaviour into account to identify spots which can trigger accidents. The evaluation is made with IST-Checklist 2005 "Exercise Booklet" – a checklist with Yes/No answer to the relevant questions. The result is numeric where a low result indicates that a critical spot or section of road has a tendency to trigger accidents. The evaluation can be used as a ground for decision making. Certification in the method is required to perform the analysis. The IST-method includes sections before and after accident location in analyzing, rather than the spots where the accidents occurred [3]. For example, it assumes a driver requires 4-6 seconds to come to a right decision during driving when a crucial situation comes up. Therefore, the analysis section starts from the critical point to several meters before the point, depending on

operating speed. IST has classified trigger factors and divided into three groups, axioms:

- Accumulation of straining points
- Signing

300-Meter-Axiom is the first rule and it treats the section up to a straining/decision point. The axiom is named after the length of the section that the driver needed to prepare before the straining/decision point. The length of the section is variable depending on driving speed and reaction time of the driver (See Figure 1). The axiom is divided into [3]:

- **Moderation of the transitional area.**
- **Straining point's perceptibility.**

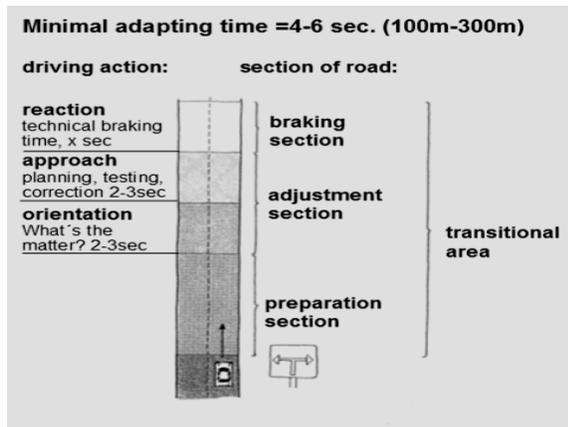


Figure 1. 300-m-axiom [2].

Field of Vision Axiom treats the roadway/ environments capability to create a simulating environment for the driver. The road with its environment together offers an integrated field of view which either stabilizes or destabilizes driver's behavior. For example a monotone environment cause fatigue which leads to speed increase or misdirection due to nonparallel lines or fences with the driving direction. This axiom is divided into three areas[3]:

- Optical density of the field-of-vision
- Lateral space structure
- Depth of space structure

The Logic Axiom treats driver's perception logic and road design. The road design has to be in accordance with the drivers expectations. For example if a road section looks or feels as a motorway, the real driving speed would be high (motorway speed) regardless the road's speed limit. The logic axiom is divided into five areas [3]:

- Avenue/town entrance effect
- City bypass irritation
- Effects of habits and routine

A Blind Test was carried out to evaluate the "IST-Checklist 2005" on the Swedish road system. This was done by comparing the results carried out from the checklist with the number of actual accidents on the road.

The IST checklist was implemented on a main road between Gothenburg and Stockholm. The road is a primary type 2-lane rural road of width 12 m , AADT of 10 000- 13 000 vehicles/day and speed between 70 – 90 km/h.

Two different road segments, A and B were chosen, one with many accidents and the other with few. The road sections have been documented in the form of photographs at a frequent interval of 20 m length. The next step was to identify straining points and divide the sections into segments. Section A, 3.6 km, was divided into 13 segments while section B, 2 km, was divided into 6 segments. All segments have been evaluated with the IST-Checklist to determine the safety level predicted in terms of numeric results. The last step was to assess the IST checklist by calculating correlation, using statistical analysis, between the numeric results of the evaluation and real accident data. Real accident data of the sections have been collected from STRADA. Accidents which were not a result of human factors have been excluded such as wildlife accidents and alcohol/drug related accidents.

ANALYSIS and RESULTS

Post-Accident Approach.

Statistical Results visualized in Figure 2 show the absolute number of accidents distributed over the six years of analysis. From the illustration it is clear that the length of the main roads increased yearly which partially explains an increasing number of traffic accidents in the region annually. However, this trend of increasing number of accidents does not mirror hazardousness inclination of the roads since other factors such as length of road section and AADT have not been taken into consideration. A short road section with little traffic flow could be more dangerous than a longer one with more traffic although the first causes less number of accidents. More about accident investigations are discussed in section 5.

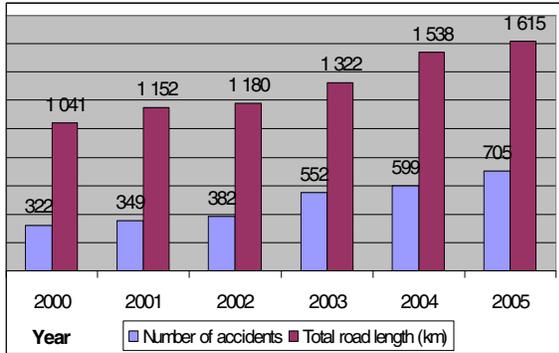


Figure 2. Number of accident together with main road length during the investigation period.

By dividing accidents according to accident types Figure 3 shows that rear-end and single accidents were the dominating accident types representing 49% and 32% respectively followed by overtaking, turning, pedestrian, crossing, head on and cycle/moped accidents.

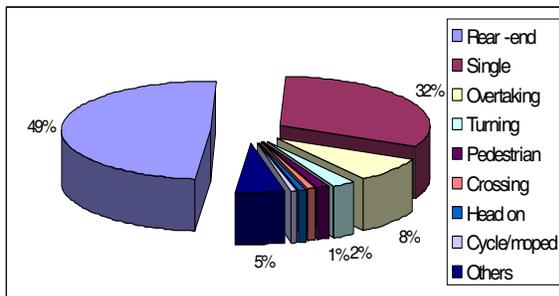


Figure 3. Distribution of accident type.

Accident Investigation by comparing the absolute number of accidents does not make much sense because of differing comparative conditions. Under comparative conditions, however, it is understood that section length and traffic volume exhibits an influence on the accident situation. For instance, the longer the roadway section is, the higher the accident possibilities are. Similarly, the higher the traffic volume is, the higher the accident possibilities are. Therefore, the length of investigated section and the traffic volume on that section (that is, vehicle kilometer traveled) must be considered in comparative accident investigations.

Accident rate (**AR**) is one way to normalize the results. It considers the length of a roadway section and the traffic volume to allow a direct comparison of different roadway sections with respect to traffic safety [6]. Accident rate (Equation 2) is accident per **Million Vehicle Kilometer (MVKm)**.

$$AR = \frac{\text{accident} \times 10^6}{AADT \cdot 365 \cdot T \cdot L} \quad \text{accidents per } 10^6 \text{ vehicle kilometers} \quad (2)$$

Where:

- AR = Accident rate
- AADT = Average annual daily traffic.
- L = Length of investigated section, km
- T = length of investigated time period, yr
- 365 = number of days/yr

After determining AR; statistical methods have been used to analyze the processed data including histogram graphs, simple and multiple linear regression analysis.

In examining the whole period, Figure 4 shows that AR is almost constant the first three years then increases rather strong after that. The substantial increase of AR in the year 2003 is most likely due to less accident report loss in STRADA rather than the roads have become more dangerous. From the year 2003 accidents from both police and hospitals have been reported to STRADA while before that only police reported traffic accident registered in OLY. A total of 297 (16%) could have been lost if only police reports considered in the last three year accident collection.

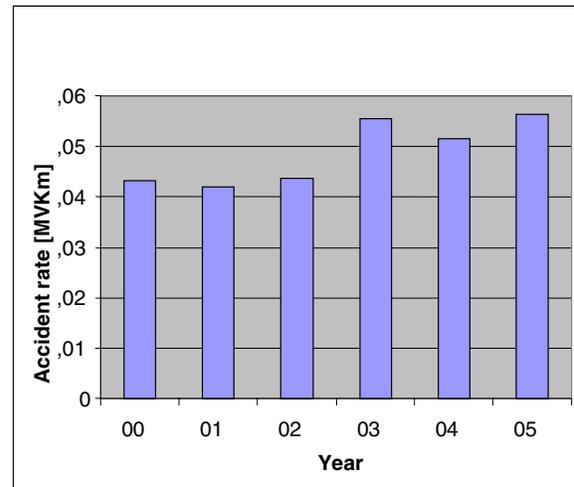


Figure 4. Accident rate on the main public roads in the Western Region of Sweden.

A comparison of the AR for various types of roads is done; Figure 5 reveals that motorways are safer than four-lane and 2+1 roads. However the AR for four-lane and 2+1 roads are almost equal.

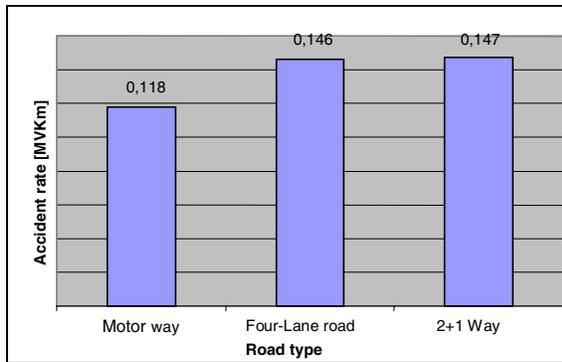


Figure 5. Accident Rate for different road types.

Figure 6 shows the outcome, in terms of injury severity, of the injured persons in the crashes investigated (based on police report information). The rate for killed persons have decreased to more than half in the year 2005 in relation to the first three years of analysis. Also severe injuries has decreased generally, apart from a deviation in the year 2005 in which the rate has increased compared to years 2003 and 2004. The light injury rate increasing is explained by the fact that accident rate has increased in the last three years (See Figure 6) fatal and severe injury rate have decreased. Light injuries increased on all three road types in the last three years, mainly on four-lane roads, while severe injuries decreased mainly on motorways. Fatalities have decreased generally on four-lane and motorway roads.

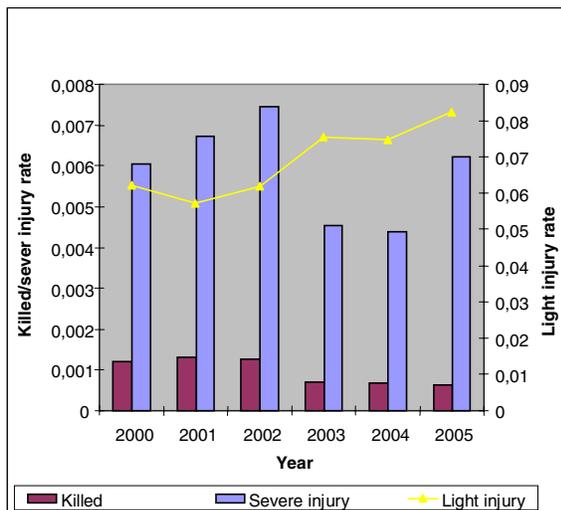


Figure 6. Injury severity rates during six years period

Linear Regression Analysis is a statistical method for modeling the relationship between two or more mentioned variables using simple and multiple linear equation. Simple linear regression (Equation 3)

refers to a regression on two variables while multiple linear regressions (Equation 4) refers to a regression on more than two variables. A statistical software program, SPSS, has been used in regression analysis to find the effect of road attributes on accident rate. The dependent Y-variable represents accident rate. Independent X-variables included road speed limit, carriageway width, curvature, grade and super elevation.

$$Y=a+b \times X \quad (3)$$

$$Y=a+b \times X_1+c \times X_2+d \times X_3+\dots \quad (4)$$

Confidence of the result indicates in terms of significant value (P). The correlation was considered significant if (P) is zero or 5 % different from zero [7]. The correlation coefficient R^2 only gives a guide to the "goodness-of-fit" or how closely variables X and Y are related. It does not indicate whether an association between the variables is statistically significant.

Expressroads haven't been considered in the following analysis due to the insufficient number of accidents. Most of the accidents have been excluded due to lack of road information. The following relationships have been drawn between design and traffic-related variables and accident history of analyzing road parameters.

Influence of Speed Limit on accident rate (for all three road types) showed that the accident rate increases as speed limit increases from 70 to 110 km/h. However when the speed limits decreases from 70 to 50 km/h accident rate increases. As expected, the injury severity increases with increasing speed limit for motorway and four-lane road accidents. The selected equations have strong regression coefficient R^2 (0.64 to 0.99). However the least significant value P; was found for motorways, 0.1.

Influence of Carriageway Width on accident rate was the following:

- Carriageway width up to 5.8 m has the lowest accident rate; they usually are one-lane roads. Accident rate was up to 3 times less than other carriageway widths.
- A distinct tendency for accident rate to decrease with increasing lane width greater than 5.8 m. The regression coefficient R^2 was 0.86. However value of P was 0.24.
- Road categories with, $5.8 < W \leq 7.5$ m, had the highest accident rate. This category represents mostly two-lane roads without shoulder or with a narrow one (See Figure 7).

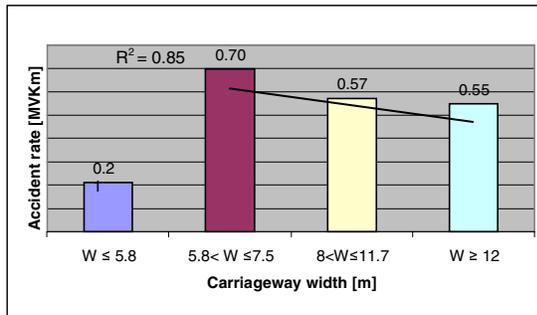


Figure 7. Influence of carriageway width on accident rate.

Influence of Curvature on accident rate has been shown in Figure 8. Statically analyzing left and right curves separately showed unchanged tendency of accident rate on curves for radii greater than 1500 m including straight sections. However a clear change of accident rate was noticed on curves with radii less than 1000 m as follow:

- Accident rate decreases with increasing radii of curve for both right and left curves with R², 0.7 and 0.88 and P value 0.16 and 0.19 respectively,
- Left-turn curves have a higher accident rate than right-turn curves.
- Road sections with left curve radii of less than 100 m have accident rate that are twice as high as road sections with right curve radii less than 100 m.
- Road sections with left curve radii of less than 100 m have accident rate that are four times as high as those on sections with curve radii greater than 500 m.

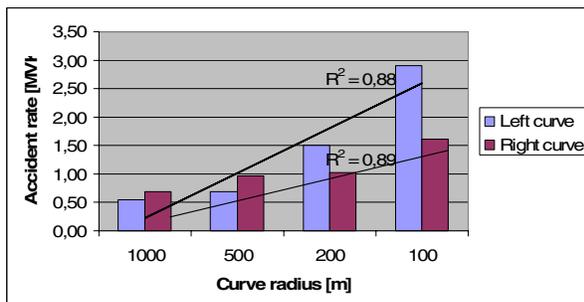


Figure 8. Influence of curve radius on accident rate.

Influence of Grade on accident rate showed:

- The accident rate on down grades is slightly higher than that on upgrades.
- Upgrades have little effect on accident rate, while accident rate increases with

increasing downgrade with R² equal to 0.7, however the correlation is not statistically significant, P = 0.36.

- A sharp increase in accident rate on downgrades greater than 4 percent.

Influence of Super Elevation on accident rate resulted (See Figure 9):

- Super elevations of between ±3 and ±4 percent exhibited the most favorable results.
- Accident rate increases significantly for superelevations greater and less than the favorable percent, ±3 to ±4. The correlation coefficients, R², are generally high. However, only increasing accident rate were observed for decreasing negative super elevation (less than the favorable value) is statically significant with a P value of 0.02.
- Negative super elevations have higher accident rate than positive super elevations.
- 0 – 1 percent negative super elevations and positive super elevations ≥ 5 percent have the greatest accident rates which are about twice as high as that on the favorable percent, ±3 to ±4.

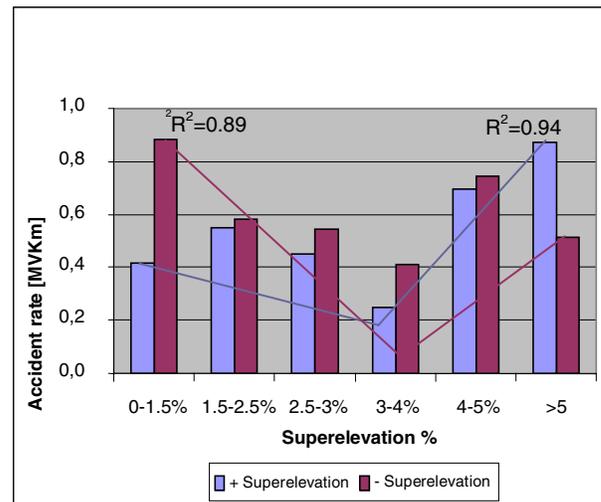


Figure 9. Influence of super elevation on accident rate

There was no significant correlation between traffic accident rate and road parameters together, when multiple linear regression analysis was applied to the collected data for all road types. The relationship did not become stronger when the SPSS program was allowed to choose parameters that together have influence on accident rate.

IST-Checklist Method 2005

Statistical analysis showed weak correlations between the low IST Checklist 2005 results and high accident frequency. The method should predict high accident rates when the checklist numerical scores are low. The overall correlation between IST and both sections was 0.05. Correlations increased slightly, but were still weak, when sections A and B analyzed separately. Results were -0.15 and 0.36 respectively.

When analyzing the sections separately according to driving direction, correlations for section A, east and west were -0.10 and -0.35, respectively while section B results were 0.63 and 0.03.

DISCUSSION and CONCLUSION

Post-Accident Approach

A Post-accident analysis approach was based on accident and road data. It is well known [10] that the reporting of injury accidents in official road accident statistics is incomplete. The fact that reporting is incomplete does, by itself, not introduce any bias in studies evaluating the relationship between road characteristics and accident rate. Results can be biased, however, if the level of accident reporting changes over time (relevant to before-and-after studies).

The locations of the accidents were only those provided by the police. An explicit assessment of the level of estimation, and its variation, is almost never done. It is, unfortunately, not possible to remove or control for this potential source of error. However to minimize effect of the errors; an average value of around 200 m has been taken for the road parameters. Another problem in determining the location of accident is when the reason of accident is not where the vehicle is stopped, which means that road measurements of another section should have used for analyzing the accident.

The Pavement Management System (PMS) was not fully accurate for estimating accident locations. In measuring the same road section, annual variations in the road geometry measurements were noticed. Parameters such as curvature, superelevation and grade have to be constant for the road section unless the section has been repaved or reconstructed. The 200 m average used in this study reduces the effect of this error source. On the other hand several sections had no measurements registered in PMS especially at

motorway exit and slipways which led to excluding 10% of total collected accidents. Most of the sections of interest were on expressroad sections which have not been analyzed due to few numbers of accidents.

The roads chosen for analysis (Motorway, 2+1way and Four-lane roads) are among the safest road types in Sweden [11], therefore finding black spots on such roads was not an easy task.

Further investigation is required to study correlation between road surface data (unevenness, wheel rut and road condition) and accident rate.

The statistical relationship results generally showed high correlation coefficients, R^2 . The main findings of the post-accident research presented in this approach can be summarized as follows:

- There is a strong statistical relationship between speed limit and accident rate, when the speed limit increase, 70 – 110 km/h, the accident rate and the severity of injuries will almost always increase. However when the speed limit decreases from 70 to 50 km/h, increases accident rate.
- Carriageway width less than 5,8 m has lowest accident rate, while two lane carriageway without shoulder or a narrow shoulder $5.8 < \text{width} \leq 7.5$, is the most dangerous.
- Accidents cluster at curves and left turn curves with radii less than 100 m.
- Superelevations of 3-4% are in the safest range. Accident rate increases with roads deviating from this range.
- Grade has a low effect on accident rate however downgrade road sections have slightly higher accident rates than upgrade sections.

Pre-Accident Approach

The safety tool “IST-Checklist method 2005” which is based on human behavior is a simple method as it is based on a checklist with Yes/No questions. However the method is very time consuming when it is applied to long road sections.

The results of this research indicate that the method does not function as expected; blind tests made on sections of a Swedish road show a low correlation between real accidents and a low result from the IST-Checklist 2005 method. This result doesn't mean that the method is not applicable as a safety tool. The result, more likely, can be explained by a number of reasons - the main one being that due to the 'human

side' of this method, the analysis is highly subjective and therefore open for individual interpretation. However, it is the authors' opinion that the method is useful in analysing traffic accidents due to its consideration of a large number of important factors when it comes to traffic safety and road design. Other possible error sources are division of segments from straining points, errors in accident statistics and the omission of traffic flow (AADT). The latter is highly relevant for safety comparisons between road sections.

[11] EuroRAP-First Pan-European Progress Report. November 2005, Published by EuroRAP AISBL.

REFERENCES

- [1] RANKERS (Ranking for European Road Safety) homepage <http://rankers.cidaut.es>
- [2] Intelligenz System Transfer (IST) (2006a), *HF guidelines, literature excerpt*, and (2006b) *IST-Checklist 2005 course material*. Potsdam
- [3] KAROLINE BJÖRKMAN & ANNEL JOHANSSON, (2006), *Safe roads through good road design based on knowledge about human behaviour,- an evaluation of the IST-Checklist 2005 method*, Master Thesis in Master Degree Program Civil Engineering, 2006:75, Department of Civil and Environmental Engineering, Division of GeoEngineering, Road and Traffic Group, Chalmers University of Technology.
- [4] Swedish Road Administration homepage (December 2006), www.vv.se
- [5] Björketun U. (2003), *Olycksdata och linjeföringsmått*. Väg- och transport forskningsinstitutet, Linköping.
- [6] / Ruediger Lamm, Basil Psarianos, Theoder Mailender (1999), *Highway design and traffic safety engineering handbook*.
- [7] Wahlgren L. (2005), *SPSS steg for steg*. Studentlitteratur, Lund.
- [8] SAAD JAMIL, (2006), *Samband mellan trafikolyckor och väggeometri*, examensarbete 2006:76, GEO-avdelningen, Grupp Väg och Trafik, Chalmers tekniska högskola, Göteborg.
- [9] Andersson J., Johansson A. (2005), *Koppling av vägdata till vägtrafikolyckor lagrade i STRADA*, examensarbete 2005:44, GEO-avdelningen, Chalmers tekniska högskola, Göteborg.
- [10] Elvik R and A.B, Mysen. (1999). Incomplet accident reporting. Meta-analysis of studies made in 13 countries. Transport research record, **1665**, 133-140.