PROCEDINGS OF THE WORKSHOP

TRAFFIC CONFLICTS AND OTHER INTERMEDIATE MEASURES
IN SAFETY EVALUATION

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The Human Factor Effect on the Road Transport Safety.

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The Prague's Road and City Transport Institution is an organization already for the third consecutive five-years plan responsible for widely extended research project called "The human factor effect on the road transport safety". Many of the problems connected with the indicated project are being solved inside our institution but some of the other specific problems are being processed by special research organizations or relevant university technical institutes. Such a research arrangement seems to be an optimal one as there is no necessity to create any excessively special workplaces of our own. Said problematics concerning the human factor really encloses a very wide possibilities indeed as it covers medical area, psychology, sociology, electronics, geophysics and also juridical aspect fields including also all the interests of individual participants of road transport themselves.

As far as the psychological research problems are concerned I'm sure my own colleagues will express their opinion of given subject.

I would like now to speak briefly about one task out of the many above specified fields of interest : it is a research design called "The geomagnetic and climatologic effects on the transport accident frequency", processed by a numerous team of different professionals. Our institute is the coordination and controlling body of this group which includes : department of applied geophysics, natural sciences college of Charles University, Astronomical Institute of the Czechoslovakian Academy of Sciences, Central Institute of Railway Health Services and the CSSR Interior Ministry as far as the detailed statistical data of road transport accident frequency are concerned, and some other collaborating organizations and authorities.

The above specified research design started already in 1971 as a long-term one owing to the necessity of using the eleven-years cycle of minimal and maximal sun activities period. After some final conclusion and analytical work this research was concluded in 1983.

On the basis of some current literature findings it could be ascertained that when the changes of geomagnetic field are occurring the attenuation in the central neural system increases and the conditioned or unconditioned reflexes are slowed down with following memory disturbance and some
further undesirable phenomena (see Chodov, 1971). Additional authors, predominantly concerned with the same research field, have found out the existence of an outstanding correlation between the accidents frequency and geomagnetic field disturbances. In view of the fact that 83 percent of the magnetically tranquil days \((k = 15)\) have had a significantly lower accident frequency, 81 percent of magnetically disturbed days \((k = 25)\) were characterized by an increased occurrence of traffic accidents.

When contemplating the geomagnetic field disturbances effect on the traffic accident frequency it was found necessary to exclude the meteorological effects that may seriously influence the results of our observation. It was therefore decided to watch in parallel with the geomagnetic field disturbances also the meteorological effects.

It should be noted of course that our attention was at the same time focused on the air ionization and geoelectric field problems. A following fact has to be taken into consideration: our atmosphere contains light, medium and heavy ions, i.e. gas molecules or microscopic particles with a positive or negative unit charge. The quantity of such positively or negatively charged particles in a single volume unit is usually called the unipolarity coefficient. Many contemporary authors are of the opinion that the feeling of fatigue and irritation or the attentiveness deterioration and reaction time increase in human is caused by an insufficiency of negative ions in the air.

The intrinsic solution of this problem in the final phase of the above specified research project was concentrated on the analysis of the entire country road transport accident frequency data, enabling us to use statistically more significant quantities. However, considering the information feedback as far as meteorological elements are concerned, we obtained a definitive "blurring" of some correlations as these effects very often have a territorially restricted performance range. Of course this indicated solution encompassed all the obtained barometric pressure levels, frontal transitions with relevant directions, geomagnetic field disturbances and all the other phenomena having the required analytical accuracy. Such a mathematical and statistical analysis leads to a proper evaluation of all such effects because all the seasonal cyclic daily, weekly and yearly accident frequencies are filtered off. As a final result we have obtained the following brief survey of meteorological and other effects in relation and correlation with the transport accident occurrence.

Statistically demonstrable increase of accident frequency was produced by the following meteorological conditions:

- \(W_{cs}\) - (western cyclonal situation with a south path), increase by up to 9 percent;
Nc - (northern cyclonal situation), increase by 4 up to 11 percent;
NEc - (northeastern cyclonal situation) increase by 3 up to 4 percent;
SWcz - (southwestern cyclonal situation with a frontal zone over Central Europe) increase by 2 up to 6 percent;
B - (low-pressure furrow over Central Europe) increase by 2 up to 6 percent;
Vfz - (frontal zone entrance) increase by 0 up to 16 percent;
C - (cyclone over Central Europe) increase by 5 up to 9 percent; and
Cy - (altitude cyclone) accident frequency increase by 4 up to 10 percent.

On the other hand a statistically demonstrated decrease of accident frequency occurs under the following conditions:
Wc - (western cyclonal situation) decrease by 3 up to 4 percent;
Wa - (western anticyclonal situation) decrease by 3 up to 4 percent;
NWa - (northwestern anticyclonal situation) decrease by 2 up to 6 percent;
NEa - (northeastern anticyclonal situation) decrease by 4 up to 5 percent;
Ea - (eastern anticyclonal situation) decrease by 8 up to 12 percent;
SWc1 - (southwestern cyclonal/meridional situation) decrease by 2 up to 4 percent;
A - (anticyclone over Central Europe) decrease by 2 up to 5 percent; and
Ap - (migrating anticyclone) accident frequency decrease by 4 up to 15 percent.

Also some transition conditions should be added to individual levels as they too have a specific effect on the transport accident occurrence.

As far as the effect of geomagnetic field disturbances are concerned, (index k > 25) we in the CSSR can expect an accident frequency increase of average 4 percent on the first day and for following two days 2 up to 3 percent. Sudden geomagnetic field disturbances in planetary measure (accident frequency increase by 5 percent) and geomagnetic storms (increase by 4 percent) form an analogous indicator. Above mentioned dependences are nevertheless statistically insignificant. On the other hand, however, a statistically significant relationship in fact was demonstrated in case of the horizontal geomagnetic field component pulsation. In case of days with the pulsation time exceeding 8 hours we in Czechoslovakia obtained an accident frequency increase of average 4 percent and this tendency was also noticeable in the following 3 days. When the pulsation duration exceeded 16 hours the average accident occurrence increased in the CSSR by 5 percent (for 9 following days).
It follows from the above discussion that both the meteorological and geomagnetical effects evidently and deeply infringe the overall road transport accident frequency.

Our attention should be, however, also directed to the effects of electrical, magnetical and electromagnetical fields. Interaction of such fields with biological objects has in the past few decades been submitted to very intensive study. Large series of experimental data give a conclusive evidence of these effects reality but, unfortunately, a reliable and generally consented interpretation of the transition mechanism is still missing. Some of the partial realities should perhaps be mentioned:

There is a lot of evidence to show that an electrical field having 10 Hz frequency (intensity 2.5 V/m) can, assuming aperiodic conditions, prevent the operation of some inner desynchronization functions. Periodic demonstration of human organism can also be affected by intrinsic bio-rhythm (frequency 10 Hz) and presumably even by natural magnetic field (Aschov, Wever 1976).

Lauterbach (1978) is of the opinion that the magnetic anomaly (caused by road rock subgrade structure having different magnetic properties) may, in unfavourable cases and assuming the normal motor vehicle speed, cause a changing magnetic field with a frequency in the proximity of 10 Hz. Such magnetic field is then, owing to brain alpha rhythm interfrequency, able to influence some of the driver psychical characteristics (e.g. activation level, attentiveness) to such a degree that it may lead to an accident (as a hypothetical explanation of frequent accidents on some road section).

König's (1974) experiments demonstrated the existence of low frequency natural electromagnetic fields influence on subjects reaction time when observing an optical task.

Altogether some additional authors have also demonstrated the influence of large geomagnetic disturbances of high intensity on the organism energetic sensitivity thresholds (Prigane, 1982); therefore the influence of geomagnetic field on the human being should be accepted as a reality. Many authors presume that just the geomagnetic field changes, usually starting on this planet 1 or 2 days after the burst of solar activity, constitute the triggering mechanism of variations in the biological processes (Cyram 1950, Muzalerská 1971). Contrary to that Dubrov (1974) assumes that the biological effects of geomagnetic storms are taking place later on, especially on the third or fourth day after the change.

None of the observed external environment effects are in our biosphere isolated, but all of them are biased in constellation with many other external factors, consequently leading to a superposition of individual effects either in a positive or negative sense with an unavoidable complex result. And the influenced system (in this case human being)
is, of course, moreover endowed by nature with many variable individual and conditional characteristics.

It is well known for quite a long time, that the human organism is able to react on the atmospheric environment changes. Individual person reactions as a consequence of variable weather conditions are usually called meteorotropismus and the weather-element or eventually weather-complex with a presupposed effect on organism is so called meteorotropic coefficient.

From the biochemical point of view Faust (1973) suggested three classes of weather receptivity with the following psychophysiological correlates:

1. Fatigue syndrome (low catecholamin level) with hypotonic manifestation, body tiredness, general apathy, depressive mood, concentration decline, ataxy, adynania and hypoglycaenia.
2. Irritation syndrome (serotonin drift) with insomnia manifestation, strain, neuralgic headache, overexcitement, throw up, dizziness and tremulousness.
3. Frustration form (mixture of fatigue and irritation syndromes with typical thyroid disorder) with characteristically increased sensitivity to warmth and coldness, palpitation and pulse acceleration, increase of somatic substances exchange, perspiration and increased activity.

Weather sensitive people do react on the variations by a disorder of total health state expressed by different adaptation levels increasing even up to pathological reactions or syndromes. Weather alone can readily affect the reactivity of people with respect to the rest of the vital load and in some cases can help in time of stress. Weather receptiveness is first of all conditional in initial state of a given organism in the symptomatic sense and in accordance with the existing negative lability. From the psychological point of view, the activation level is almost certainly a relevant factor, because either too high or too low activation level decreases the reaction reliability (Bures 1967).

The percentage of weather sensitive people in total population is estimated at the average 30-40 percent, that being a very significant proportion. To analyse the complex meteorological factors effect is, particularly if we include the effects of transition paths on human being, absolutely exceeding the scope of this rather brief abstract of said research project.

Taking into consideration the research work done in years 1971 up to 1983, we can conclude by specifying the following basic points:

1. It was clearly demonstrated, that the meteorological factors are affecting the drivers psychical state of mind.
2. Such effects of drivers by said meteorological factors
are characterized by outstanding individual differences.  
3. The reaction ability of drivers could even be affected by exterrestrial and geophysical energy emissions.
4. In accordance with specified research work there exists a definitive correlation between the accident frequency and geomagnetic activity having a pulsating character.
5. In all here described correlations we found the intervention of cyclic variation effects.
In the ČSR there are now altogether 18 working groups or sections covering the transport psychology within the framework of different road and city transport organizations. Some of them are located in the ČSR Automobile Transport concern, others in different City Transport Organizations and the rest in the Regional Transport Centres. In all there are recently 31 psychologists with a corresponding number of assistants; as an exception also some sociology specialists are on their staff (+).

(+): A complete list of these sections could be obtained from the author; it was also published in the Czech journal "Psychology in economic practice", 17, 4, 193–199, 1982.

Logically the work functions of such sections first of all cover the professional drivers (or the applicants for that job), psychological examination and evaluation of their mental fitness for driving. Such psychological examinations are usually done in the following cases:

- when employing new drivers;
- when reclassifying some already employed drivers;
- when for some reasons the periodical reexaminations are required;
- in connection with some serious or frequent traffic accidents;
- when the medical organizations or police or juridical authority request so. The functions of these sections include also:

- consultation service (in personal or labour matters);
- participation in research investigation cases;
- cooperation, forming and realization of the organization social development plan.

A qualified high-school educated psychologists are in charge of all the specified sections. Their direct superior is usually either the deputy director or the manager of personal department. Of course in both cases as far as psychology is concerned only the psychology specialist decision is important.

The Prague’s Institut of Road and City Transport (ÚSMK) was in accordance with the ČSR governmental decision (1975)
and in agreement with ČSR Interior ministry degree of transport director (1978) commissioned to supervise the methodology of individual sections.

This methodology is within our ÚSMÚ Institut applied by psychologists of the VÚ 114 section assigned to research department VO 14.

The methodology control is realized by means of the following activity:

- individual consultations;
- planned visits of individual sections;
- special long- or short-time instructions and practical training arranged at the ÚSMÚ Institut;
- editing and distributing the advice or necessary documents (e.g. methodology of research reports, instructive notifications and official directives);
- correspondence (e.g. psychological evaluations and analysis);
- oral sessions and meetings with any transport personnel from ČSR, working on any sort of research project;
- by organizing special seminar or courses for transport psychologists from ČCSR (usually every year).

In the course of daily supervizing the methodical functions the staff members of ÚSMÚ psychology section acquire many valuable informations and knowledge concerning:

- concrete problems connected with normal or special investigations of drivers;
- opinions, attitudes and reactions of drivers and their direct superiors;
- the effectivity of individual tests and psychological examinations;
- working capacity and possibilities of individual psychological groups and sections;
- the importance of statistical results acquired by psychological examinations in a given period;
- any difficulties, misunderstandings or conflicts that may occur are decidedly decrease the work effectivity of psychological sections.

Acquired knowledge (either in the form of individual communications or elaborated documents) is by the ÚSMÚ staff of psychological section or laboratory processed and adapted or integrated and in accordance with relevant requirements returned to individual sections in the form of guiding provisions, instructions or directions and distributed as necessary.

It also should be said that the obtained information could be used in many other regions as e.g.:
1. For research and development purposes in the field of transport psychology concerning:
- traffic accidents analysis,
- the problematics of different behaviour in the transport sphere, and
- engineering psychology as a special branch of activity.

2. For cooperation with universities, colleges or technical institutes (especially with the psychology department, philosophical faculty of Prague's Charles University), for any advice concerning the required special diploma of students studying transport psychology.

3. For the eventual requirements of medical sector, police investigation groups of juridical authorities (as detailed later on).

4. For the exchange of knowledge and experiences with similar Slovakia organizations or psychology sections.

In a rather rare case that the methodology control is not systematic and the information and feedback flow are seriously impaired, the above specified aspects and concepts might be disturbed; that consequently has a detrimental effect on our work as described in the following two paragraphs:

I. There exists and steadily increasing lack of uniformity in psychological investigations, in results evaluation and drivers judgments. (These harmful tendencies are rather regular, because there always are new workers, tendency to simplify problems, make things easy, underestimate some aspects or just an inclination to try something new and original).

Necessarily this means that, consequently, loss of individual sections coordinations would, after some time periods, lead to incomparable work results and to low performance capability.

A proper methodology should, as a matter of fact, keep all the functions in acceptable proportions: workers should have, on one side, the feeling of some freedom of action but on the other one any investigation should fulfill all necessary requirements, and simultaneously the comparability on admissible level. In addition also all the investigation records should be made in a standard way so that all the results could be statistically analysed by the same method.

II. If the methodology supervision is not fully systematic, the responsible transport organization authorities may have a warrantable conviction that the subordinate psychological section is not working properly. Such examples have already been recorded, often accompanied by discrepancies in other directions.

The staff of ÚSMO psychology section as far as methodology is concerned obtained all the necessary commissions, e.g.:
- statutory position of specialists in methodology covering
many possibilities (and responsibilities as well) to collect and analyse any special and administrative data needed for the development and progress in transport field:

- Feasibility to obtain all foreign special literature (books, journals etc.) through the mediation documentary ÚSMD section (securing also an ČSSR library exchange service and translations);

- Easy contact with any Prague organizations with similar interests and aims (e.g. psychology department of philosophical faculty of Charles University, Central Institute of Railway Health Services and different Socialities and Police Transport Inspectorate of Prague etc.);

- A possibility to attend practically any professional actions (lectures, symposia, conferences, seminars etc.) appertained to work and transport psychology.

The above described methodology in supervising and control of all psychology sections should be done in close collaboration not only with medical organizations but also with any other relevant medical establishments.

On the contrary many medical organizations, establishments, boards and departments are time from time requiring our help and are applying to ÚSMD psychology section for:

1 - Psychological examinations in case of controversial or problematic problems connected with capability to drive road motor vehicles. Such examinations are usually done in periodical intervals, but lately, owing to deficient capacity, such cases are rather exceptional;

2 - Advice concerning some special psychological problems. For illustration the most frequent advices are connected with the following cases:

   - When a driving licence has to be obtained for a person having a lower intelligence, partial deafness or alcoholism; or for a person after a head injury or brain-shock and persons hot-tempered or violent;

   - When an increased accident frequency is caused by inherent (and lasting) or situational (and temporary) factors or by rather a set of misfortunes;

   - Problems connected with the Health Ministry decision (1963), specifying some defects and diseases leading to inability to drive a motor vehicle. Such defects or diseases are, unfortunately, listed without any quantitative or qualitative measures whatsoever (e.g. the emotivity defects as far as unbalance and incontinence are concerned).

Such and similar advices are according to their importance answered individually, orally or in writing. If they are made by other resorts (not directly connected with transport authorities), answers are usually given by an intermediary action, as for example a special seminar. In the course of the last five-years plan approximately eight such seminars were realized. In such a case the psycholo-
gists of ŠKMD give lectures about the ability to drive a motor-vehicle safely. Also some suitable courses covering the driver’s problems are arranged for specialists of other transport organizations. (The objective control of drivers testimony concerning the transport accidents or driving difficulties is of great importance for a correct evaluation; the same holds good when considering the records in driver evidence cards at the pertinent transport inspection or the driving examination results. A maximal circumstance is here really necessary, as we may find many drivers trying to disimulate and conceal or suppress some relevant facts).

As the outcome of these considerations clearly shows it is predominantly the medical sector, where the complex and effective evaluation of drivers ability brings significant economic benefits. Problematical drivers are either incapable of normal work or are doing something of subsidiary value. If they are driving motor vehicles, they are dangerous as far as health and property damages are concerned. Unfortunately the special seminars actions are not of the institutional character; it could be realized only on the basis of personal contacts. In accordance with author experience the medical services are only incompletely, inaccurately and vaguely informed about the ŠKMD activity. Another advantageous social co-operation with medical services could be expected in case of medicament effects on the psychic of drivers and in case of older drivers-amateurs ability to drive (this research project was started at the beginning of the last five-years plan).

The author of the present report is definitely convinced about the importance, responsibility and economic benefits of methodology used by ŠKMD for the supervising of the transport psychology sections everywhere. Such activity, however, would need a capacity of at least two specialist-psychologists with an assistant.

The function and working plans of psychology specialists also include the following duties:

- popularisation of transport psychology field (using press, broadcast and television facilities);
- publication of reports in special and popularization journals;
- preparation of necessary documents for transport and other authorities;
- many other activities (e.g. preparation and verification of new psychological tests and actions for the investigation and evaluation of drivers, juridical expert’s account service, selection and assortment of optimal apparatus for testing purposes etc.);
- cooperation with the Slovakienv, RVHP and foreign transport psychologists.
Conclusion note and author's recommendation.

It is perhaps fair to declare that due to the above described facts the methodical supervision of psychological sections included in transport organizations definitely has its place in the scientific and technical revolution and in modern development of our society. Such activity either statutory or economical or personal is, therefore, important and desirable and first of all socially and economically significant; for this reason it should be, if possible, fully realized.
This study gives a survey of results of the traffic accident set analysis provided by the research team in the framework of the task "The Clinical Analysis of Traffic Accidents of Selected Sets in CSR and SSR", that was realised by Research Traffic Institute in Žilina.

Two teams working according to the same methodics were set up to try to solve this task. Various special professions were represented in both teams, especially those having a close contact to problems of safety in traffic – traffic engineer, road engineer, medical jurisprudence traumatologist, traffic psychologist, transport engineer.

The methodics of research ensued from the result of the previous periods, the aim was to gain the maximal number of data and knowledge to each followed accident which could contribute to make clear its origin, course and consequences. A special functional group made the own notes and photodocumentation directly at the place of accident, where it was asked to be on the base of an agreement with both police and first-aid station immediately after an accident. The data were coded into the single forms especially intended on the individual elements of traffic system – car, road, driver.

On the basis of the gained data each expert of team worked out an evaluation of the given accident from the point of view of its specialization /for instance – with a view to road marking or traffic marking, state and surface of the road, technical state of the car, global state and qualification etc./.

The knowledge of each specialization were integrated at team consultations and the partial conclusions were completely worked out in the form of research information. Owing to the complex analysis of causes and course of the traffic accidents a great number of measures was suggested to increase the safety of road traffic, first of all as to road marking, constructional changes of vehicles, organizational measures in traffic, instruction and training of drivers, judging the state of health of drivers.

The main task of psychologists of the Institute for Road
and Urban Transportation in Prague was to follow and evaluate the influence of the human factor as to the origin and course of an accident situation, namely in two aspects. First, to evaluate the direct participation of a driver, let us say, of his mind and behaviour in the origin and course of a traffic accident, and second, to analyse those factors which could have negatively influenced the full applying of driver's psychological functions necessary to drive a car in a safe manner.

The data to evaluate an influence of human factor as to the origin and course of an accident situation were gained by means of detailed questionnaires, personal debates with accident drivers, medical documentation, documentation of traffic accident or directly by psychological consultation of an accident driver in the psychological laboratory of the Institute for Road and Urban Transportation in Prague. The Alternative Methodics of Testing Psychological Qualification for Driving Motor Vehicles that was worked out in this Institute and is applied in many psychological centres of road and traffic enterprises, was used to do the psychological consultation. To take part in this consultation was voluntary, so that we sometimes failed to require objective data, especially in the case of those drivers causing serious traffic accidents and being rightfully suspected of reduced psychological qualification. In some cases, when the accident was caused by a professional driver, a psychological consultation of an enterprise traffic psychologist was for our disposal.

In the questionnaires for accident drivers there are the data following their state of health before the accident (the longer lasting diseases, too), state of mind, interpersonal contacts before accident, way of living and the whole regime, enough sleep and rest before the critical travelling, momental conducting leading into the accident, doing in the course of the accident, subjective evaluation of the causes of the accident, present time practice in driving motor vehicles and a serie of the other auxiliary data.

The conclusions of the analysis of the five years period were worked out and summed up in the final report in 1985. A traffic accident was considered to be the result of a serie of factors where being breaking down of human factor the most important of them. Another important knowledge were required in the sphere of the construction and equipment of vehicles, parameters and quality of road communications, mechanism of wounding and injuring of travelling persons. These knowledge were maximally employed to make suggestions and measures to improve the safety of road traffic.

The following knowledge were gained from the standpoint of the human factor:

The wrong manner of driving was most often cause of a traffic accident, then it was breaking priority in driving.
Further, inadequate speed, especially of young unexperienced drivers and wrong overtaking. These causes and its order more or less correspond to the national-wide statistics of traffic accidents.

Except for these evident, noted causes deeper causes were determined reflecting the origin of an accident situation and its development towards the traffic accident. The insufficient, superficial exploration of the given traffic situation together with the slight anticipation of its further development appeared to be the most often and most consequential cause of wrong and dangerous traffic conducting. This cause is probably connected with the fact the majority of the registered accidents occurred in the place the driver passed daily or very often what led to the decrease of attention and watchfulness. The overstress caused by a great quantity of means of travel equally appeared as very dangerous in the same way as the dispersion of attention or its concentration out of driving motor vehicle (for instance personal problems and troubles, straying in an unknown terrain, blind and complicated road junction).

Also the inadequate perception and evaluation of road traffic had its influence on accidents, above all as to density of vehicles and pedestrians, owing to the real state. The ability to judge adequately a traffic situation and adapt one's traffic conduction is connected with driver's experience, ability of anticipation, way of perception, cognitive capacity etc.

It was the desinformation that contributed to the accident in several cases, too, a wrong understanding of the intention of the other participant of the traffic situation.

Affecting of driver's mind by his unfavourable state of health or by taking alcohol represents a very weighty and dangerous cause in its consequences.

The conditions were chosen as well (subjective and objective) which existed being catalysts in the moment of accident or which became the accident factor (in the sense of overstressing the driver's psychological capacity). We must first of all take into account those organizational defects as building repairs of the road and of its near surroundings, diversions, temporary direction of traffic, broken traffic lights, wrong architectonic construction of communication and its surroundings when the outlook and orientation are aggravated in the crossways.

The factor of mental load in the form of personal, financial and working problems, conflict family home, mental unsteadiness and lower tolerance to attacking of unfavourable stimulations in the road traffic, finally, incompetence to drive motor vehicles because of bad health in both mental and physical aspect, all those are the factors which mostly ap-
peared to be the subjective conditions.

The realized psychological consultations of the accident drivers signalized the defects in their personal characters and mental functions, especially in their perception. These characters of the personality were evaluated to be unfavourable from the point of view of safe driving of motor vehicles: emotional unsteadiness, unrespectableness in conducting, lack of criticism to the own abilities and consequences of conducting, irresponsibility, aggressivity, intolerance to the faults of other participants of road traffic, tendency to risk, immaturity of personality in the whole.

There was a weight fact regarding the following driver's career that only a small part of the accident drivers was able or ready to formulate their share in causing the accident, to be aware of fault and to confess it. On the contrary, there was an evident effort to bagatelize all the situation saying "anything like that could happen to everybody".

The decisive part of the accident drivers already was the participant of an accident and confessed a number of traffic offences.

These concrete knowledge led to the suggestion of measures to improve the safety of road traffic aimed at the human factor. It was, for instance, recommended: to take into account the future safety in constructing communications as soon as they are in the phase of being planned, to do away with objective defects that could lead to relapses of trouble incidence, to test consistently the competence of drivers with regard to their health, to continue to struggle against alcoholism, to pay more attention to the instruction of drivers and the publicity of motoring.

Finally, still an illustration of a traffic accident from the point of view of the human factor:

Traffic accident No. 266

The accident occurred at twenty past 2 p.m. In the time of the accident the street was sprinkled by a road sprinkler, other contiguous streets in the direction of running of the accident vehicle were dry.

The driver of the mass city transportation was late because of technical defect and was sent with the vacant bus to the next terminal station. He started to overtake a car before the crossways, he went in the left part of the roadway into the street. There was a load carrier coming in the opposite direction, that's why he tried to come back to his part of the roadway, however he skidded and the bus stopped to be controllable and both vehicles came into collision.
Consequences of the accident: considerably high material damage, grave injury of the load carrier driver and death of his assistant.

The driver of the bus I.M., 25 years old, single, no children, motor mechanic, two years professional driver in Prague Traffic Enterprise. In the drivers past there are 5 traffic offences confessed - high speed, 2 accidents - side and back clash. In the case history there is a series of injuries - fractura of forearm, collar - bone, knee, lacered wound of ear, left heel, knee. He had not undergone psychological assessment when coming to work to Prague Traffic Enterprise.

Psychological consultation in IRCT:

Common mental functions (I.Q., memory, vigilance, reaction time etc.) quite comply with the normality, serious exceptions however, must be taken to the characters of personality. The driver manifested a tendency of frivolity, low anticipation, impulsivity of conducting, bad moments of self-control, immaturity of personality and some infantile aspects in conducting and answers.

The day before the accident he ran at about 120 km up to the morning shift and slept 4 hours.

The cause of accident: crossing over the opposite direction, high and risky speed, unsuitable characters of the driver I.M. with regard to driving motor vehicles, lack of sleep. The sprinkling of the street without any warning starting in the half of the street behind the crossways contributed to the accident, too.
The analysis of drivers' escapes from an accident place as a source of information about traffic safety

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The problem of drivers' escapes from an accident place we can analyse from four points of view. The law aspect and moral aspect concern a road users. The formal and situational aspects belong to traffic organization and to traffic safety. This article touches all kinds of aspects.

1. Law problems of escapes from an accident's place.

The road accidents are non-typical criminal acts. Theoretically, each of road users could meet such a situation. The accidental impendence grows parallel to enlargement of vehicles and acceleration of their speed. The consequences of road accidents are nasty.

From the law point of view, the traffic accidents are always connected with material damages and very often with people's injuries and human death. There are two main law problems:

1) The punishment for breaking law, which was a reason of the accident.

2) The victims of accidents satisfaction for their injuries and their material damages.

In the punishment aspect we ought to remember that the traffic accident is the mainly unintentional transgression, very often for no reason whatever. Therefore, the restriction for traffic accidents are rather mild. However, that mild punishment may be used only under specific conditions. The causer ought to care of victims and to organize the first aid for them. If that activity is not realized, the court could raise the punishment.

The problem of the financial satisfaction is basically solved by obligatory insurance for all owners of vehicles. It allows to pay the compensation for all victims regardless to wealth of causer of the accident.

However in the law and financial aspects of an accidental situation, we could find several main principles, which ought to be respect.

The first condition says that the causer must be sober.

The second condition touches the necessity of adequate driving licences of all drivers, who took part in an accident.

The third condition is related to a road technical state of vehicles of all drivers, before the accident time.
The fourth condition is the complete control the postaccidental situation by police investigation inspectors. Below, we present several facts about law aspects of drivers' escapes from places of accidents. There are results of the analysis of 86 cases of drivers' escapes from accident places in the Cracow province during the last six months. The tables show only factors which were of frequent occurrence (max) and in exceptional cases (min). The characters of each of presented situation was defined in two categories: randomized factor (RF) and unrandomized factor (URF).

Table No 1
The Alcohol using in the accidents with a driver's escapes (URF)

<table>
<thead>
<tr>
<th>pos.</th>
<th>the kind of road users</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max 1</td>
<td>Drinking drivers</td>
<td>15</td>
</tr>
<tr>
<td>Min 2</td>
<td>Drinking pedestrians</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Alcohol using unidentified</td>
<td>76</td>
</tr>
</tbody>
</table>

Table No 2
The main reasons of the accidents with a driver's escapes (RF)

<table>
<thead>
<tr>
<th>pos.</th>
<th>the kind of the accident's reason</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max 1</td>
<td>The pedestrians inroading</td>
<td>18</td>
</tr>
<tr>
<td>Max 2</td>
<td>Unlimited speed of vehicles</td>
<td>17</td>
</tr>
<tr>
<td>Min 3</td>
<td>The skill of vehicles</td>
<td>1</td>
</tr>
<tr>
<td>Min 4</td>
<td>The lack of good protection of children, disables and older people</td>
<td>2</td>
</tr>
</tbody>
</table>

2. Formal aspects of drivers' escapes.
The basic duty of everyone, who participate in accident is to stay right at the place and wait for ambulance and police is coming. That duty is not compulsory only for causer who organize first aid for victims and for causers, who could be lynched by furious crowd.

The staying at the place of an accident is very important for qualification of character of an accident. The policemen must make identification of participants of an accidental situation, reasons of the accident and point the accident's causer. The process of liquidation of an accident contains several duties, as: investigations about injuries and data of people, who were transported to the hospital, the primary expertise of damage vehicles, and then the decision what to do with them. The attendance of participants of accidental situation allows for inspection their personal documents and for control of their sobriety.
Therefore each escape or even short time going away of participants of an accidental situation (especially the causer) making the process of liquidation of an accident difficult or impossible. In such a situation, the road traffic organisation has to have possibility to make the escape impossible or to hold the causer if he has begun to escape. We ought to remember that the escaping driver is very often desperate and his driver's behaviour is very dangerous for other road users. Therefore, police in all countries have a special training and special strategy for stopping and holding the drivers who escape from the accident place.

From the result of our analysis, we present several data about the formal aspects of drivers' escapes.

Table No 3
The causes of the traffic accidents connected with a drivers' escapes (URF)

<table>
<thead>
<tr>
<th>pos.</th>
<th>the kind of road users</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. 1</td>
<td>Car drivers</td>
<td>52</td>
</tr>
<tr>
<td>Max. 2</td>
<td>Pedestrians</td>
<td>35</td>
</tr>
<tr>
<td>Min. 3</td>
<td>Bus drivers</td>
<td>2</td>
</tr>
<tr>
<td>Min. 4</td>
<td>Tractor drivers</td>
<td>1</td>
</tr>
</tbody>
</table>

Table No 4
The participants of the traffic accidents connected with a drivers' escapes (URF)

<table>
<thead>
<tr>
<th>pos.</th>
<th>the kind of road users</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. 1</td>
<td>Pedestrians</td>
<td>60</td>
</tr>
<tr>
<td>Max. 2</td>
<td>Car drivers</td>
<td>35</td>
</tr>
<tr>
<td>Min. 3</td>
<td>Motor cyclist</td>
<td>4</td>
</tr>
</tbody>
</table>

3. Moral aspects of the drivers' escapes:
The road is the meeting place of people from various social groups, of different characters and different human worth. Travel by car is permanent coming and outgoing of social contacts with other road users. The contacts between the drivers of driving past cars are not too long (just several seconds) and afterwards they immediately disappear. The accident stops this bond of superficial contacts just as stopping the frame of film. Two or more unknown each other road users could be tied by strong relation suddenly. That relation influences very intensely upon their lives. The road accident is the special form of interpersonal relation between road users on the material base. Very often the accidents connected with damages and injuries. One can be a causer and one can be a victim of an accident. Somebody made an error and the others could be disabled for
all their one’s life by this error. Very important problem touches the blame of accident’s participants. Many times the real causer of an accident is a driver or other road user, even they didn’t find fault with him. The classical example shows the colleagues who were drinking alcohol with the driver, before he caused the accident.

The problem of guilty is not only the law, but also the moral category, very often. The accident could influence stronger the moral attitude of causer, than the hard punishment.

Therefore the temptation to devolve the responsibility for accident is very strong. In the causer’s opinion it is possible only by the escape from the accident’s place. He disregards the duty of aid to victims because he thinks that the escape guarantees him anonymity and impunity and protects against other unpleasant consequences of accident. The "attractiveness" of the escape must be considered by the causer. It determines the further behaviour of the causer.

From the psychological point of view, the most important moment is the time of decision making of escape. The psychological investigations of drivers’ escapes ought to concentrate at that point.

The second important factor is a causer’s position in relation to victims of accidents. It is clear, especially in “the drivers— the pedestrians” or “the drivers— the cyclists” accidents. The driver has bigger, quicker and stronger vehicle. It gives him better position in that situation. He runs away from the accident’s place and he is sure, that he won’t be chased.

The third factor, which makes motivation to escape, is causer’s unsobriety. That problem was already discussed together with law and formal aspects of the escapes.

It is necessary to point the moral causers of the accidents, who run away from the place without any consequences, for ex. pedestrians who has jumped on the road and provoked the drivers to sudden stoping their vehicles and broke them, the drivers who has uncorrectly used their vehicles’ lamps by night and dazzled other road users, who has made an accidents because of that etc. It is very difficult to chase those people because the accident’s participants could not remember any details about them (reg. number of car etc.). The next results of our analysis characterize of the moral aspects of drivers’ escapes from an accidents place.

Table No 5
The victims of a traffic accidents (URF)

<table>
<thead>
<tr>
<th>pos.</th>
<th>the kind of road users</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max.</td>
<td>1 Pedestrians</td>
<td>90</td>
</tr>
<tr>
<td>Min.</td>
<td>2 Motorcyclists</td>
<td>4</td>
</tr>
</tbody>
</table>

In each decision of escape making, we could find some elements of realistic evaluation of situation. The refugee ought to make, even superficially, evaluation of his escape possibility, to cover up tracks, at last, the possibility of recognition of him by victims or witness. It is sure, that he would inspect mainly the factor, which make the escape easy. Some categories of accidents could be connected with the escapes of causers.

The first cluster of facts, which is conductive to escapes are: the time conditions. The night time and the darkness make causers’ identification more difficult and do not show the way of his escape. Sometimes the night hours mask the accidental situation, especially, when the broken vehicles or victims are moved to the side space of the road. During the night time the number of road users is rather small. So there are very few people who could observe the accident and raise alarm.

The weather conditions play similar role. Rain, fog, snow very effectively cover up trucks and making difficult identification of accident’s causers. Bad weather stops the pursuit or makes it difficult.

The third group of facts are topographic conditions. The character of area could be conductive to causers’ escape. From the traffic organisation point of view we distinguish build area (cities and villages) and non build over area (other areas).

In the empty area the refugee has a better chance, because the lack of people and their homes allows him to run out unnoticed. Other area factors: big woods, hills, many secondary roads are very good for refugees.

At las, the next group of factors, which are conductive to escapes are: traffic control and traffic organization. The small number of regular police stations makes possibility of alarm difficult, when the road accident has happened. The staff of those stations could observe the road users and note for e.g. damaged vehicles, drinkers etc.

The second problem is a small number and weak activity of moving police traffic patrols, which could observe the roads of big traffic or with a great number of accidents. It allows to get quick information about undesirable events in traffic. The helicopters or plane patrols are very useful for the roads with big intensity of the traffic.

It is clear, that police information system ought to cooperate with a good system of analysis of traffic accidents. It allows
to show a dangerous places of the roads, to define main reasons of the accidents and to analyse all facts of drivers escapes. The next factor is the well working system of the road communication, which allows inform about accidents quick.

Very important too for escape's prevention is a quick system of information about road users which reports immediately about the basic data of refugee (his address, type and colour of vehicle etc.) The special police system of way stoping, which orders to limit possibility of escape.

At last, the judgement system ought to treat the escaping drivers very seriously by the serious punishment and confiscation of their driving licenses.

Finally, we present the last table with the data of analysis of drivers escapes:

Table No. 7
The places of the accidents with a drivers escapes (RF)
N = 86

<table>
<thead>
<tr>
<th>pos.</th>
<th>The kind of accident's places</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. 1</td>
<td>the quarters of the Great Cracow</td>
<td>34</td>
</tr>
<tr>
<td>Max. 2</td>
<td>the non build off area</td>
<td>23</td>
</tr>
<tr>
<td>Min. 3</td>
<td>Cracow center area</td>
<td>7</td>
</tr>
<tr>
<td>Min. 4</td>
<td>Cracow near-center area</td>
<td>9</td>
</tr>
</tbody>
</table>
II. INTERMEDIATE MEASURES

Grayson, Graham  Intermediate measures for traffic safety - an overview

Muhlrad, Nicole  Application of traffic conflicts and other intermediate measures: an overview

Zimmermann, Günter  Situation-related safety criteria in road traffic

Harmath, Peter  Speed-selection in conflict situation

Hocherman, Irit  The use of systematic behavioural observations to evaluate a change from two to one way street

van der Horst, Richard  Road user's decision making in traffic - some examples

Case studies - current application of Traffic Conflicts in the UK

C. J. Baguley
To say that accidents are the traditional method of measuring traffic safety is to do no more than to state the obvious. To go further and say that accidents are the only possible and legitimate measure of traffic safety would be just as obvious to many people working in the field. However, there are reasons for thinking that this statement may not be as obvious as it seems at first sight. First, there is the example of other systems where safety is involved. In aviation, accidents are (thankfully) rare events, and much effort is devoted to the study of incidents where accidents have been avoided - strangely termed near misses. Similarly, industrial safety studies rely heavily on the investigation of critical events, where circumstances combine unexpectedly to make an accident likely, but where it is averted. Second, there is some debate about what 'safety' means. It seems that safety is one of those concepts that can only be described in terms of the absence of its opposite, as for example the absence of accidents, or freedom from danger. But if one talks of danger or risk, this ought to include the subjective as well as the objective elements. How the subjective elements should be incorporated into the framework of safety evaluation is still a matter of much debate, but it is widely agreed that they cannot be ignored, even though their relation to accidents is often ambiguous.

Accidents, then, are the traditional measure of safety, but not necessarily the only possible measure. To a large extent it depends on one's standpoint, and whether one is a researcher or a practitioner. Traffic safety research is concerned primarily with understanding the system; practitioners are concerned primarily with management and control of system. Control means manipulation in order to obtain results, and in the great majority of cases results are equated with the reduction of accidents. Thus support for the 'accidents only' view is strongest among the practitioners of traffic safety, who far outnumber the researchers.
The literature on traffic safety research shows that there has long been a search for ways of assessing traffic safety through the use of indirect or intermediate measures as an alternative or as a complement to accident data. The aim of this paper is to provide a short background to these ideas, and to introduce some of the issues that will be discussed at more length in later sessions.

Over the years, the list of intermediate measures that have been proposed has become both extensive and varied. Physical layout, geometric characteristics, operational features, flow levels, and numerous aspects of individual and interactive driver behaviour have all been invoked at various times in the past. (One procedure advocated in England many years ago involved the measurement of glass and plastic debris at intersections - and was able to show a good relationship with recorded accidents at those locations). The reasons for the search for intermediate measures have been stated many times in the past, and are almost as varied as the measures themselves; they range from practical considerations such as dissatisfaction with the quantity or quality of accident data, through moral considerations about the need to identify and eliminate hazards before they cause injury or death, to simple scientific curiosity about the nature of inter-relationships within the traffic safety system. The objectives of these searches are equally varied. At one extreme there is the aim of prediction, which is concerned solely with the statistical problems of assessing the accident potential of locations; at the other is the aim of interpretation, where the emphasis is on the formulation and testing of hypotheses about the safety (or unsafety) of the traffic system.

It is possible to discern two approaches that have been adopted in indirect safety measurement: the statistical, and the behavioural. The statistical approach is usually concerned with the physical and operational properties of the system, and aims to establish functional relationships between accidents and a variety of continuous variables. A large number of such variables in the past have been concerned with geometry, reflecting a belief that good design principles can minimise accident rates. Curvature, sight distances, gradient, and lane width are only a few of the many variables that have been studied, either alone or in conjunction with vehicle flow data. The history of the statistical approach has been one of only mixed success, but much has been achieved in recent years with the development of more powerful multivariate techniques, and it is
now possible to provide designers with quite reliable estimates of the expected accident rates for certain types of location.

This procedure of developing accident prediction functions would seem to have much to recommend it; however, it also has its drawbacks. To start with, the functions are derived from sample data, and are limited by the size and representativeness of the samples; bigger ones may yield different functions. Then, the functions describe relations that may change over time, either gradually or in response to some external factor. However, if functions are found to change, it is very difficult to determine whether this reflects a real change in the underlying relationships, or if it is merely the result of using different or better data. Finally, statistical functions, however sophisticated, only describe relationships, and do nothing to explain them. In summary, this approach has proved to be very helpful to designers, but is of less value to practitioners than might appear at first sight, since being able to predict accidents is far removed from being able to prevent them. For researchers the same argument applies, except that here the aim is to understand accident causation. In short, accident prediction is only a means to an end, and that end is accident reduction. There are many who believe that adopting the behavioural approach may be the best way of achieving that end.

The behavioural approach to the indirect measurement of safety has many similarities with safety activities in other areas, such as aviation and industry, as was pointed out earlier. Though not as old as the statistical approach, it too has a long history, and the list of variables studied has become extensive over the years. It includes traffic violations, headways, driver errors, gap acceptance, hazardous manoeuvres, and near accidents—or conflicts. These items all have in common that they are discrete events, and that they are regarded as being in some way a deviation from 'safe' behaviour, in that their occurrence is likely to increase the probability of an accident. With some items, for example traffic violations, the relationship with accidents may not always be clear. However, the claims for the strongest candidates on the list are based on the assumption that there exists a continuum of events, ranging from normal 'safe' driving practice through events that become increasingly critical, and culminating in accident and injury. The study of behavioural measures of the behavioural type can be seen as being synonymous with the study of critical traffic events, one of which is the traffic conflict.
The existence of such a continuum seems inherently plausible, but it should be noted that it conveys two important implications. The first is that the nearer an event is to the accident end of the continuum, the easier it is to demonstrate that it has a high probability of leading to an accident; in other words, it has validity. The second is that the nearer an event is to the 'normal' end of the continuum, the more frequently it will occur, and the easier it will be to show that estimates of its occurrence are reliable. These two issues of validity and reliability are fundamental to any discussion of intermediate measures in safety, as can readily be seen from the literature on traffic conflicts. They also mean that the choice of an intermediate measure is always to some extent a compromise between collecting the 'best' data and collecting enough data. In a similar way, it could be argued that there can be no such thing as the 'best' intermediate measure in absolute terms, only the best for a particular purpose.

As far as application is concerned, the study of critical traffic events can be either prospective or retrospective. It may be employed to estimate the expected accident rate at a particular location, either to assess its hazardousness, or to assess the effects of some form of alteration to that location. Alternatively, it may be used to diagnose safety problems by being able to draw on a data source that is much richer than that provided by accidents alone. Both approaches depend on having first demonstrated the validity of the measure being used. Without validity, prediction is impossible, and diagnosis is pointless. How to set about establishing validity and what criteria should be employed are still the subject of much debate in this field. However, wider acceptance of intermediate measures will almost certainly depend on producing convincing evidence of validity - however that is defined.

Although using behavioural measures as surrogates for accidents may have attractions for practitioners, and is an essential step in establishing validity, it nevertheless only begins to realise the full potential of the technique. For practitioners and researchers alike, the real value of intermediate measures will be found in solving problems, rather than in measuring effects.

While it would be inappropriate for an introductory paper to offer conclusions (since that is the purpose of the sessions to follow), it may be helpful to review the main points that have been raised. First was the question of how to measure safety,
and why this is necessary. Then it was suggested that willingness to consider indirect as well as direct measures often depended on the objectives adopted. Two main approaches to indirect or intermediate measures have been identified, the statistical and the behavioural. The statistical approach is capable of producing powerful results, but it was argued that the behavioural approach can make a better contribution to accident reduction. The assumed continuum of behavioural events was discussed, which led to the fundamental issues of reliability and validity. Critical events in the traffic system can be studied either as surrogates for accidents, or as sources of information for diagnosis. Both activities require that the events studied can be shown to have a valid relation to accidents.

Finally; although the emphasis in this paper has been on indirect measures, it must be stressed that the direct and indirect approach to safety measurement should not be seen as opposing alternatives, but as complementary. Both are needed in order to tackle effectively the problems of traffic safety.
APPLICATION OF TRAFFIC CONFLICTS AND OTHER INTERMEDIATE MEASURES : AN OVERVIEW

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INTRODUCTION

Research on traffic conflicts and other intermediate variables has always been field-oriented. The need for a diagnosis tool to complement accident data in safety studies was first expressed by local traffic safety engineers in the USA, who applied for several years a simplified form of standardized observation. The relationship between the traffic events observed and actual accidents was however soon considered too loose, and research took up from this point to develop a better technique. The same pattern of events occurred in some European countries, in particular in Finland, where the administration of Roads and Waterways attempted some early practical applications of the traffic conflict concept, before turning to research.

Although the need for intermediate measures originally emerged from safety workers in the field, most applications so far have been carried out by researchers. Traffic conflicts in particular have proved a valuable research tool. Lack of flexibility of national guidelines defining "appropriate" safety measures, and lack of incentive for honest evaluation of the effects of local safety work may be, in some countries, part of the reason why local authorities, or local branches of national road administrations, did not favour in the past the use of intermediate variables.

This trend seems now to be reversing. It is gradually becoming clear that safety measures, to be at the same time effective and reasonably cheap to realize, should adapt very closely to the local problems at hand, and that their design therefore requires a thorough knowledge of the causes of unsafety and the way behaviour can or should be influenced. More and more safety schemes are thus experimental, and their effects must be assessed in the short term. Local governments and safety workers are consequently getting interested in intermediate variables, not so much for use on highways any longer, but rather on rural access roads and in urban areas. Communication between research and practice is now reaching a critical point.

The following overview is an attempt at covering most of the fields in which traffic conflicts or other intermediate variables have been applied. It is based on published documents, and the studies explicitly mentioned are only examples to illustrate a general trend and do not constitute an exhaustive listing of what has been done in the matter. Also, the fact that prac-
tioners tend to publish less on their work than researchers reduces the amount of information available on local experimentation...

DIFFERENT TYPES OF APPLICATIONS OF TRAFFIC CONFLICTS AND OTHER INTERMEDIATE MEASURES

Nine or ten Traffic Conflict Techniques (TCTs) have now been finalized, and are well documented and ready for field-use. All of them include standardized procedures for traffic observation, and can be applied to a rather wide range of issues:

1 - As accident-surrogates, traffic conflicts are useful to carry out short-term evaluation of countermeasures. Such "product-evaluation" normally involves before-and-after studies, with controls (when possible). Effects of experimental schemes can be quickly assessed, for instance in the few months following implementation, and the variations of these effects with time can also be monitored by repeating conflict observations during the "after" period and comparing results. Some methodological precautions must be taken however, when evaluating a scheme that radically alters local traffic conditions: the conflict-to-accident ratios may not be the same "after" than "before", and comparisons between the two situations must therefore be carried out in a qualitative rather than a merely quantitative way (the total number of conflicts observed may well increase, while predicted danger decreases).

There have also been attempts to use traffic conflicts for the identification of safety problems in situations where accident data was entirely missing or thoroughly unreliable, as for instance in some developing countries. The validity of results obtained is yet unproven, but it is clear that a standardized procedure to observe traffic should lead to less biased conclusions than a more subjective assessment of danger formulated without any guidance.

2 - As a complement to accident data, traffic conflicts have often been used for safety diagnoses and countermeasure design. On locations where accidents are, statistically speaking, infrequent, or when detailed accident data is not available, conflict observation gives valuable indications as to the causes of unsafety and the way to avoid it. Even when accident analysis is conclusive, conflict data can help design countermeasures which also ease the task of pedestrians or drivers, and are more acceptable to road-users in general.

Conflicts are also more and more used in addition to accident data in evaluation studies, to show, not only whether a safety measure works, but also how it works (or why it doesn't). Such "process evaluation" (or qualitative evaluation) is a way of checking the assumptions made when designing countermeasures, and should provide directions for improvement or changes.
Safety diagnosis and process evaluation are the two main tools available to local safety professionals to keep training themselves, increase their practical knowledge, and develop their own work, and these particular applications of TCTs should therefore become much wider-spread.

3 - Conflicts as themselves are now currently used in research studies to assess road-user performance or risk, or to analyse the concept of "subjective safety". In evaluation studies, they are also used as indicators for the quality of life environment, a traffic conflict being considered in itself as an element of stress that should be avoided, and a malfunction in the traffic system.

Other possible intermediate measures mostly include various procedures of behavioural observation (including monitoring speeds) or traffic counts. They apply to three main kinds of tasks:

- safety diagnosis on hazardous locations or performed in view of area-wide safety measures. Behavioural observations are defined on the basis of what is known from accident (or conflict) data, and are used to check the first assumption made on the causes of unsafety. Traffic counts are often used as background data;

- process evaluation. Behavioural observation or other intermediate measures are used to check that the "intermediate aim" of a countermeasure (for instance reducing speed, altering pedestrian crossing behaviour, raising drivers' awareness, etc.) is actually reached. While this may not always mean that the countermeasure will be effective in reducing accidents, it is on the contrary quite clear that if it does not fulfill its intended intermediate aim, it cannot have the expected effect on safety either. Intermediate measures are also used to check that a countermeasure does not produce unwanted side-effects which could reduce its final efficiency; traffic counts and sometimes speeds are the most frequent detectors of side-effects...

- evaluation of some preventive safety measures such as educational or training programmes, information campaigns, etc. Such measures appear impossible to evaluate with the more traditional means (before-and-after accident comparisons with control groups), and well defined behavioural observation is likely to be the only way to ever assess their effects.

When compared to TCTs, other intermediate variables show a major drawback: they are not standardized, and a specific procedure must be designed again for each new case. Research may ultimately produce guidelines to facilitate the task; in the meantime, most evaluations carried out on the basis of behavioural observations have been the fact of researchers rather than practitioners.

Finally, new evaluation tools such as measuring the levels of "subjective safety" experienced by road-users, or their degree of satisfaction after countermeasures have been implemented, have appeared in the last few years, both in studies carried out by researchers and by local authorities. Although such indicators cannot be termed as "intermediate variables" as there does not seem to be any direct connection between "feelings of safety" and
an actual potential for accidents, they are used in a very similar way as an additional part to "process evaluation", when the aim of the countermeasure tested is actually twofold: improving safety, but also life conditions. This is often the case when area-wide schemes are designed for urban neighbourhoods. Subjective safety and the road-users' degree of satisfaction are also measured to gain knowledge of countermeasure acceptability.

PRACTICAL APPLICATIONS OF TRAFFIC CONFLICT TECHNIQUES

Diagnosis and evaluation studies based, totally or in part, on conflict data started being carried out ever before TCTS were completely developed or validated, and are now quite numerous. Not all of them however were successful or conclusive, but they all contributed to throw some light on the problems related to unsafety and countermeasure design. A number of studies are therefore mentioned here as representative of various fields of interest, but no results or critical viewpoints are given.

1 - Research applications

They include studies carried out by researchers themselves (although often in relation with national or local road administrations), but exclude development research (test of TCTS, validity, calibration).

Research applications of TCTS can be classified as follows:

1.1 - TCTS as a research tool for behavioural analysis and the study of risk and subjective safety

In these applications, TCTS are often associated to other forms of observation, and sometimes to interviews of the road-users observed. Studies of risk-estimates by road-users at intersections were carried out in England (G. GRAYSON, in /5/), while the relationships between subjective feelings of safety and conflicts and other traffic events were investigated in France (N. MUHLRAD, in /3/, D. CIER and al. /16/). TCTS were also helpful for the assessment of drivers' performance, in particular in studies carried out:

- in Austria, on car drivers (R. RISSE, A. SCHUTZENHOFER, in /5/): a typology of driving errors was built, and specific behaviour of particular groups of road users (foreign through-traffic) was analysed (R. RISSE, in /12/, /13/);

- in England, on car drivers, with comparisons between night and day driving behaviour (J. DARZENTAS, V. HOLMES, M.R.C. Mc DOWELL, in /2/);

- in Hungary, on car drivers at hazardous locations or in specific traffic situations (overtaking, crossing intersections, at railway/road level crossings, etc.), (M. DRASCOCZY, in /13/);

- in The Netherlands, on bicycle riders at intersections (E. TENKINK, in /13/).
1.2 - Conflicts as a tool for safety diagnoses and countermeasure design

In these applications, TCTs are mostly used to complement accident data; the conflict data collected is thus necessarily detailed, and descriptive of the traffic processes leading to critical situations. Black-spots or hazardous locations were particularly investigated this way; for instance:

- in Austria, in urban areas; follow-up studies were also carried out on the countermeasures designed (installation of islands and pavement markings). (K.J. HOFFNER, A. SCHUTZENHOFER, in /2/);

- in France, in rural and suburban areas (G. MALATERRE, N. MUHLRAD, in /2/);

- in Israel, within a project of residential area improvement (A.S. HAKKERT, in /5/);

- in Austria again, where an international conflict study took place and produced safety diagnoses on rural and suburban intersections which are "seasonal" black-spots (the Trautenfelds study, in /12/, J.H. KRAAY, A.R.A. VAN DER HORST, in /8/).

Safety diagnosis has also been carried out on specific traffic situations, as for instance in Germany on bicycle traffic at 45 intersections (G. RUWENSTROTH, in /13/).

Finally, attempts at using existing TCTs or derived techniques in replacement of missing accident data to identify or analyse specific safety problems have also taken place within the framework of scientific cooperation with Developing Countries, in particular in the City of Nairobi, Kenya (cf. C. HYDEN), and in two provinces of the Republic of the Philippines (N. MUHLRAD, in /17/>.

1.3 - Traffic conflicts as an intermediate variable for the evaluation of safety measures

Quite a number of new countermeasures or experimental schemes have already been subjected to short-term evaluation based on conflicts. Some of the studies carried out were only concerned with "product-evaluation" with conflicts as the safety indicator in before-and-after comparisons, while others were rather more qualitative, with conflicts as one of several measures used to assess "process" and effects; in particular, TCTs and some behavioural observations were often associated. The main categories of countermeasures investigated are the following:
- junction lay-out: left-turn facilities in urban areas were studied in Germany (G. ZIMMERMANN, G. RIEDIGER, in /4/) as well as in Norway (F.H. AMUNDSEN, H.O. LARSSON, in /1/), mini-roundabouts in suburban areas were investigated in England (J.J. OLDER, J. SHIPPEY, in /1/), and safety of at-grade and grade-separated intersections on rural highways was also compared in Norway (F.H. AMUNDSEN, H.O. LARSSON, in /1/);

- traffic light installment and operation: the effects of turning traffic-lights to flashing amber at night or off-peak hours were analysed in Israel (D. MAHALEL and al., in /4/, A.S. RAKKERT, in /5/), in France (N. MUHLRAD, G. DUPRE, in /5/), and in Norway (F.H. AMUNDSEN, H.O. LARSSON, in /1/). Comparisons between different forms of traffic-light operations were carried out in France (G. DUPRE, in /5/), and in Germany (G. HOFFMANN, R. SLAPA /11/), and the effects of installing traffic lights at urban and rural intersections were followed up in England (J.J. OLDER, J. SHIPPEY, in /1/);

- facilities for unprotected road-users: different types of pedestrian crossings and refuges were studied in Austria (L. SCHUTZENHOFER, in /2/), in Finland (R. KULMALA, in /3/, /4/), and in France (G. DUPRE, in /5/). Experimental cycleways were investigated in The Netherlands (A.R.A. VAN DER HORST, in /3/, /4/, /5/), and priority zones for bicyclists in Germany (G. RUWENSTROTH, in /13/). The evaluation of specific safety measures for unprotected road-users is also the object of continuing research in Sweden (cf. S. ALMQUIST);

- speed reduction measures in urban areas: the effects of speed humps, road constrictions, special paving, etc. were assessed in The Netherlands (A.R.A. VAN DER HORST, in /5/), in Sweden (C. HYDEN, P. GARDER, L. LINDERHOLM, in /4/), and in Germany (H.W. FECHTEL, W. RUSKE, in /10/), while speed limits in school areas were investigated in Sweden (C. HYDEN, in /1/);

- area-wide measures in urban areas: new schemes or experimental projects for traffic restraint or speed reduction in residential areas were evaluated in The Netherlands (V.A. GUTTINGER, in /1/, /5/, T. JANSSEN, in /7/, and J. KRAAY, J. GOOS, in /13/), in Germany (R. ALBRECHT, in /4/), and in Sweden (C. HYDEN, P. GARDER, L. LINDERHOLM, in /4/);

- highway design: in Europe, TCTs were less used in research on rural safety than in towns. However, the effects of acceleration lanes at grade separated intersections on a four-lane divided highway, and of the replacement of a crawling lane by an overtaking lane have been studied in Finland (R. KULMALA, in /3/, /4/).
1.4 - Traffic conflicts as a pedagogical tool

Intentions of using traffic conflicts, and in particular video-films of conflicts actually observed on the road, as an educational tool have been expressed in several countries. Practical applications are actually taking place in Sweden (cf. C. HYDEN, S. ALMQUIST).

2 - Applications of TCTs by National Road (or Safety) Administrations

National Road Administrations started working with the TCTs in the early 70's, mainly in the USA and in Finland. Swedish and Dutch Administrations became interested a little later on, than the French one, although in a limited way. The main applications can be classified as follows:

2.1 - Diagnosis and countermeasure design on hazardous (or potentially hazardous) locations on highways

These activities have been systematically carried out, both in Finland since 1972 (M.J. MERILINNA, in /1/, R. KULMALA, in /5/, U. LINDSTROM, in /13/), and in Sweden (M.O. MATTSON, in /5/). In Sweden, it is now a continuing task, with one or two new cases investigated each year.

Apart from hazardous junctions, the Finnish Road and Waterways Administrations has also been studying climbing lanes, and petrol-filling stations (R. KULMALA, in /3/, U. LINDSTROM, in /13/).

2.2 - Evaluation of safety measures

This kind of work is less common than safety diagnosis, and is mostly now in preparation or in progress. The effects of installing traffic lights on a highway junction were studied by the Swedish Road Administration around 1982 (M.O. MATSSON, in /5/), and the Swedish Traffic Safety Administration is now currently investigating 2 to 4 cases a year of new or alternative countermeasures. Several projects were announced by the end of 1984, as in Finland evaluating changes in speed limits (R. KULMALA, U. LINDSTROM, in /13/), and in The Netherlands 10 to 15 other evaluation studies (J. KRAAY, J. GOOS, in /13/).

2.3 - Promoting TCTs for local safety work

Although this is not in itself an "application", it is worth mentioning that several national administrations now play an active part in promoting the use of TCTs in local traffic safety work. In particular:
- recommendations for wider use of TCTs have been issued by Transport Canada in the 70's (J. LAWSON, in /3/), a task which is now taken up by British Columbia Insurance Corporation (G. BROWN and al. /6/); recommendations were also issued by the Ministry of Transport and Public Works in The Netherlands (G. GOOS, in /13/); finally, after successful validation of the American TCTs, the Federal Highway Administration is encouraging as widely as possible its applications as a tool to predict danger before accidents actually occur (D.J. MIGLETZ, W.D. GLAUZ, K.M. BAUER, in /9/, and W.T. BAKER, in /13/);

- the National Road Administration in Sweden has organized a training programme for local road administration personnel, while in France, CETUR (Centre for Urban Transport Studies, Ministry of Planning and Transport) has recently been offering training seminars and information on TCTs to local authorities participating in the national programme "Safer City, Accidentless Neighbourhoods".

3 - Applications of TCTs by local authorities

Little data is available on the work carried out by local authorities, who do not usually feel compelled to report on it... However, we know that training packages or manuals exist in several countries (for instance in Sweden, Germany, Great Britain, and France), and that TCTs are actually in use in many cities or rural districts.

Local applications of traffic conflicts seem to have been mostly restricted so far to safety diagnoses, as an addition to what little information is available on accidents. This is the case in particular with a number of British local authorities (G. GRAYSON, in /5/), in Norway (F.H. AMUNDSEN in /1/), and with at least one large city in Sweden, Gothenburg (B. WASSENIUS, in /7/, /13/). Some local authorities also envisage to use TCTs systematically on rural access roads, where accident information is scarce (BRAMWELL, in /13/).

Two French cities, Rennes and Müritz, are now applying a TCT for the evaluation of area-wide improvement schemes, within the national programme "Safer City, Accidentless Neighbourhoods".

It is clear that evaluation work with traffic conflicts has often been impaired by the fact that conflict observation is time-consuming and relatively costly. Local evaluations can be carried out only if some local personnel can train as observers and perform the field-investigations on their regular working time. Local authorities with limited personnel often have to give up conflicts...

PRACTICAL APPLICATIONS OF OTHER INTERMEDIATE VARIABLES

We will give here a few indications of what can be done in this field, but it is in no way exhaustive!
1 - Behavioural observations as a complement to accident analysis for diagnosis or process evaluation

For this kind of task, the observation procedure is defined in view of the first conclusions of accident (or conflict) analysis. Applications have been made in France to black-spot treatment (F. FERRANDEZ, D. FLEURY, G. MALATERRE, in /16/), in Denmark to the evaluation of safety measures in a residential area (U. ENGEL, in /4/), or in the Philippines to safety diagnosis in some critical situations as overtaking or crossing a junction with a STOP sign (F. SAAD, in /18/).

2 - Behavioural observations as a surrogate to accident analysis

In this case, the observation procedure is defined in view of the assumptions made as to how a countermeasure or particular features of the traffic environment should influence road-users. Applications have particularly applied so far to the traffic problems opposing car drivers and unprotected road-users. For instance, space-sharing by pedestrians and vehicles was studied in England (E. DALBY, in /15/), and in France (N. MUHLRAD, J.L. MONSEUR, in /14/); junctions or experimental cycloroutes were investigated in The Netherlands (A.R.A. VAN DER HORST, in /4/).

Behavioural observation has also played an essential part in the evaluation of educational programmes, as for example in The Netherlands (J.A. ROTHENGATTER, H.H. VAN DER MOLEN, in /4/).

3 - Speed measurements

They are used to test the intermediate aims of countermeasures and apply therefore mostly to speed reduction devices and area wide improvement schemes for residential areas. Sometimes, speed measurements can also indicate undesirable side-effects of other countermeasures.

Testing speed limits has been done almost everywhere. Speed humps were thoroughly investigated in England (C.J. BAGULEY, in /4/), and area-wide measures in Denmark (U. ENGEL, L.K. THOMSEN, in /5/), and in The Netherlands (T. JANSSEN, in /7/); a new type of street design for speed reduction in a town centre has been monitored in Münzig, France. Finally, speed changes at junctions on new cycloroutes were analysed in The Netherlands (A.R.A. VAN DER HORST, in /4/). These are only a few among many examples...

4 - Traffic flows measurements

They are usually used to monitor traffic restraint schemes, or indicate possible side effects of countermeasures, as in the case of speed humps for instance (C.J. BAGULEY, in /4/). Other attempts at using traffic counts as accident predictors have so far been successful only under limited conditions, and have not really been very much applied in practice.
5 - Measurements of road-users satisfaction

Variations in the level of road-users satisfaction have been measured by researchers to assess the acceptability of various countermeasures, especially for speed reduction, for instance in Norway (F.H. AMUNDSEN, S. LUNDEBYE, in /4/), in Australia (R.E. BRINDLE, in /4/, /7/), in Great Britain (C.J. BAGULEY, in /4/), and in The Netherlands (J.H. KRAAY, S. OPPE, in /7/). Practical applications of such methods have also been undertaken by local authorities in order to evaluate some measures on criteria not directly related to safety, but complementary, for instance in the City of Amsterdam in The Netherlands (P.W. VAN DER KROON, in /4/), or in the towns of Münzig, Corbeil, etc. in France within the programme "Safer Cities, Accidentless Neighbourhoods".

CONCLUSION

Applications of traffic conflicts and other intermediate variables are expanding, but not as quickly in practice as safety work would require, due to various problems, of which the main ones are unsufficient communication between researchers and field-workers, and economical restrictions. The new orientation of traffic safety work towards more localized and experimental measures or safety schemes, which is now observable in many countries, should make intermediate variables even more useful in the future.

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For some time now, a growing interest has been shown – particularly in discussions between international experts – in the investigation of the situation-specific likelihood of dangerous situations developing into ones where damage or injury occurs. The obvious need for additional measures for the short-term assessment of situation-related safety in road traffic led the Federal Highway Research Institute to form a project group with the task of assessing the state of research in this field and of drawing up recommendations for future investigations. The individual tasks of the group were as follows:

- Development of situation-related research which pays special attention to the interaction between data relating to traffic and the traffic environment on the one hand and behaviour on the other.

- Description of situation-related non-accident measures.

- The possible use of these measures when diagnosing danger and monitoring effectiveness.

- Recommendation of suitable subjects for research and the development of relevant projects.
THE TERM "SAFETY"

When dealing with the tasks, it became necessary to examine the term "safety in road traffic". The result has been an outlining of the general conditions for danger and safety. Accordingly, non-accident safety measures can involve the recording of the various forms of dangers, the people or objects exposed to danger, dangerous conditions and concrete risks. These measures may either be derived from the infrastructure, traffic or vehicles, or may be connected with behavioural aspects, e.g. intended or anticipatory behaviour in traffic or even acceptance and feeling of safety.

THE TERM "SITUATION"

Since these measures are intended to be used for assessing the safety of specific traffic situations, it is important to describe and discuss the term "situation" and the approaches derived from this term before proceeding any further with the question in hand. It was concluded that a "situation" represents more than simply a momentary recording of events in traffic using measures describing the traffic facilities and the environment. Rather, it also incorporates information on the behaviour of the road user and the attendant informal rules of behaviour. In general, theoretical approaches which deal with the term "situation" include in their investigations the complexity of conditions and the related factors under which action takes place. Thus, in this respect, they clearly differ from approaches in which individual components are analysed. "Behaviour setting" is proving to be a useful and promising integral concept for the use of non-accident measures within a model.
SITUATIONAL FEATURES OF EVENTS IN TRAFFIC AS INDICATORS OF DANGER

The evaluation of safety using situation-related criteria should be based on a concept which views traffic as a system. The traffic situation can then be determined via the interaction of the various specific forms of the components in the system. The situation is delimited by objective geometric features of the traffic facilities, the quality of the traffic facilities with regard to guiding road users, the regulation of the traffic flow, the traffic task set by this and temporal limits. As a rule, specific types of behaviour by road users should be anticipated when designing traffic facilities. A comparison between the behaviour anticipated when designing the facility with the actual behaviour reveals situational features of events in traffic which serve as indicators of "unsafety". These can then be used for forming situation-specific safety criteria.

Situation-specific considerations are also contained in orientation concepts for the road network. These distinguish between three different levels of action:

- orientation within the network
- guidance through features of a traffic facility
- regulation of traffic behaviour.

A general concept of traffic behaviour can be derived from this and similar approaches. When simplified, this can be taken to include the plan of the action, the preparation of the action and the execution and monitoring of the action.

The influencing variables of the behaviour or action may be assigned conditions which endanger safety and which vary according to the situation, thus requiring different measure-
DANGEROUS BEHAVIOUR

Dangerous behaviour in traffic may be characterised by "critical" incidents:

- speeds, decelerations or accelerations which are inappropriate to the situation
- driving manoeuvres which are inappropriate to the situation
- distances between vehicles which are inappropriate to the situation
- driving problems
- infringement of traffic regulations
- traffic conflicts.

The critical incidents may be dangerous to different degrees. This is determined by the accompanying (largely unknown) likelihood of the incident developing into an accident and the severity of the accident which may be expected in each case. It is difficult to determine the type or number of the critical incidents to be ascertained for each case in such a way that they correspond to the economic operational limitations as determined by the function of the investigation in question.

Possible starting points for the situation-related safety measures emerge from characteristics of the movements of road users in a specific area of observation:

- Speeds
  Critical time-distance relations where safe encounters between road users become "unsafe" must be given for specific constellations in traffic situations. Any act of exceeding a situational limit value for speed would be considered a critical incident.
- **Lines of movement**
  Road structures and road markings define carriageways and lanes which determine general and safe lines of movement. These theoretical lines of movement do not necessarily have to concur with those which are ideal from the point of view of the dynamics of driving. Any act of leaving the theoretical line under very specific spatial and temporal conditions may be termed a critical incident.

- **Distances (spatial and temporal)**
  During interaction between road users, the distances maintained between road users - whether temporal or spatial - may fall below which are values which are inappropriate for the situation. The degree of inappropriateness may be determined from the amount of space and time required to compensate for chance or unpredictable changes in behaviour.

- **Driving problems**
  These are recognised through uncontrolled vehicle movements and the exceeding of situational speed limits, through dangerous driving below critical limit values, by vehicles leaving their lanes or by driving in the wrong direction.

- **Infringements of traffic regulations**
  Infringements of road traffic regulations are often critical incidents which only lead to accidents on rare occasions. However, they are useful for characterising the specific problems in a situation which are related to the needs of road users.

- **Traffic conflicts**
  A traffic conflict is a visible critical incident in which road users come so close to one another (both from the point of view of space and time) that a collision becomes increasingly likely. By way of example, a conflict may be
shown by critical manoeuvres such as sudden changes in speed and direction which are aimed at avoiding a collision.

Behaviour-oriented observations, counts and measurements will refer to road users, vehicles or driver-vehicle systems. A system-oriented investigation must then attempt to differentiate between the features which have been ascertained and allocate them to the system components and functions accordingly. It follows that, when ascertaining incidents and critical incidents in road traffic, all relevant information must be co-ordinated with regard to time, location, the parties involved and situational conditions.

VALIDATION

However, critical incidents as situational safety measures must be theoretically, quantitatively and empirically examined with regards to their relationship to the construct "road safety" (which it is not possible to measure directly) and to the accident sequence. Accident data present the most important points of reference here, although they are not the only criterion. In order to improve the preconditions for the validation, the critical incidents, characteristics and accident data must be recorded and processed in an objective, reliable and representative manner which is specific to the situation.

With regard to the testing of the validity of the non-accident measures and their theoretical preconditions, it would appear expedient to

- compare measurable patterns in traffic behaviour with respect to movement, speed and interaction with corresponding patterns for accident cases,
- use temporal characteristics, relations, series and distributions for comparisons,
- summarise comparable situations into categories and thus obtain data on accidents and critical incidents which enable a quantitative analysis,
- concentrate validation on situation-specific accidents.

**DIAGNOSIS OF DANGER AND EVALUATION OF MEASURES**

Situational safety measures which have been found to be valid and useful may be used to diagnose danger and evaluate the effectiveness of measures. There is an urgent need for these safety measures to be used for such purposes. The diagnosis of dangers must enable possible dangers and their conditions to be deduced before an accident occurs.

Approaches for the situation-related diagnosis of dangers are given in the recommendations for official analyses of accident black spots (elimination of accident spots) and the technique of traffic conflict, which is primarily used in research. In addition, the evaluation concepts "positive guidance" and "accident surrogates" which have been developed on behalf of the United States road authorities contain a wealth of information and ideas on the form and content of analyses to diagnose dangers.

Results of more recent studies indicate that the use of the concept "road behaviour setting" would prove useful for the purposes of diagnosing dangers. This concept brings together the conditions of the traffic facilities and the behaviour of road users in different circumstances. It also allows the spatial and temporal delimitation of situations into examinable units and allows behavioural patterns which characterise the traffic flow and road safety to be recognised and explained. In addition, any diagnosis of dangers must
also consider the question of "safety reserves" which - as defined in temporal and spatial terms - must be available in order to be able to compensate any unexpected incidents, disruptions or environmental influences. Finally, questions of subjective safety, full consideration of possible dangers (assessment) and the temporal distribution of specific incidents in road traffic must also be taken into account.

Evaluation research in the sense of research into the effectiveness of a measure involves the identification of the intended effects and side effects of the measure and an explanation of the connection between measure (cause) and effect. A distinction is made here between "formative" and "summative" evaluations. Formative evaluation involves the collection and evaluation of information before and during the development of measures. Summative evaluation refers to the collection and evaluation of information in order to assess whether the implemented measures have achieved the desired effects and to determine which other effects have been produced in the process. The principle aim of local safety measures should be to reduce the number and consequences of accidents in the area affected by the measures and in the system as a whole. Since it is only the end result (product) of a measure which is measured when monitoring an accident, this form of evaluation is known as "product evaluation". The evaluation of measures cannot simply rest content with determining the end result, but must also establish how this result came into being. If one examines how the intermediate aims - which should be laid down in the safety concept on which the measure is based - are reached, this represents a check on the process initiated by the measure with the aid of situational parameters; this is known as "process evaluation". In addition to determining the areas affected and monitored and considering temporal aspects, practical effectiveness checks also raise the question of the determination of theoretical and limit values; in this connection, one of the prime needs is the development
of criteria of behaviour in traffic which is appropriate to the situation.

COLLECTION, COMPILATION AND INTERPRETATION OF THE PARAMETERS

However, conclusions on dangerous conditions and concrete dangers can only be made by combining the variables which describe the traffic process with the framework measures relating to construction, operation and traffic, and with measures relating to road users and means of transport. Procedures are available for collecting information connected with situation-related safety criteria and for assessing dangerous conditions. Depending on the starting position and on the purpose of the assessment, these procedures range from assessments based on the general state of knowledge, inspection of specific traffic spots and analyses of weak points through to complicated traffic surveys and investigations accompanying drivers as part of detailed studies to diagnose danger and monitor effectiveness. For reasons connected with the economics of research and the techniques of assessment, a decision will have to be made – based on the purposes of the individual investigation – as to which measures and which combinations of measures are suitable for characterising the level of safety most accurately. Possible methods of measurement include a simple counting process without use of special measuring units, local traffic measurements, the use of film cameras and video recorders, measurements taken by specially equipped vehicles and either stationary observations or observations made while accompanying drivers.

The measures and values obtained should then be specifically combined and interpreted during a hypothetically based situation analysis. Here, "interpretation" means assessing the level of safety for the period of time and space under observa-
tion, whereby the determination of concrete dangers, of the
dangerous conditions and safety reserves must be included.
In doing this, the observed and measured values must be set
in relation to limit values which mark the transition from
a safe process to a dangerous one. Particular importance
must be attached to determining limit or theoretical values
which present a number of difficulties with regard to content
and method.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research investigations in this field will examine
situation-specific interactions between traffic facilities,
the traffic environment and the behaviour of road users (in-
cluding vehicles). Concepts will need to be developed which
use the term "safety" in a context which, in addition to
accidents themselves, also incorporate dangers, risks and
their conditions. The project group therefore recommends
that the following subjects be dealt with on an interdis-
ciplinary basis:

- improvements to the situation-specific conclusions drawn
  from accident analyses.

- the selection and validation of situation-related safety
  measures.

- the evaluation and operationalisation of models for situation-
  related behaviour in traffic.

- the determination of theoretical and limit values which
  characterise a traffic process appropriate to the situation.

- model studies with situation-specific measures related to
  the diagnosis of dangers and the monitoring of effectiveness.
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"Situation-related Safety Criteria in Road Traffic"

Project Group of the Federal Highway Research Institute
Accident Research Department
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SPEED - SELECTION IN CONFLICT SITUATION
The Effect of Individual and Situational Characteristics

SUMMARY: In this paper the author presents a part of his research series for the drivers' speed-selecting and speed-changing behaviour. The results were achieved in created conflict situations and using natural observation series. The measurable variables were successfully determined from which four indexes could be defined. Using these indexes typical speed-behaviour patterns were identifiable. The correlation structure of these indexes was proved. On the basis of this typical speed-behaviour forms were presented on a conceptual level. These are as follows:
- Non-braking - fast - over-braking - impulsive;
- braking - slow - anticipating - unimpulsive.

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This paper reports on a part of a multi-phase observation series. In the research the speed-selection and speed-changing behaviour of drivers was examined. Besides the conventional observation methods we analysed results produced in created conflict situations and other experiments. The results presented here are of one of the parts of the research series.

The study had two aims. Our methodical aim was to find the measurable variables through which the typical speed-selection and speed-changing behaviour in road driving situations can be well defined. The second aim was to find these typical speed-changing behaviours and to explore whether there is any relation between them and drivers' opinions concerning causes of traffic accidents and speeding as well as themselves and other drivers.
Experimental situation: subjects of the experiments /n=25/ had to drive to a distance of approximately 60 kilometers on road. The reason to choose such a long-distance driving task was that by the time the drivers reached the critical parts of the road where the observations were made they would show their natural driving attitude. The drivers were informed that they were to take part in an observation of the psychological characteristics of fatigue. Their behaviour was observed and their speed measured in two critical situations, both of them approximately 50 kms away from the starting point. The first was a signed zebra crossing on the road /in a non-urban area/. Our pretrained associate pretended that he crosses the road within a short distance of the approaching car. In the other situation a curve was hidden behind a gradient, both of them signed. In both situations a portable radar set type PC 22 was used for quasi-continuous speed measuring. There were three measuring points situated as follows: the first /M₁/ was at the zebra crossing, the second and third /M₂, M₃/ on the two sides of the gradient forming one logical unit.

Characteristics of Measuring Point M₁: at this point there is a zebra crossing painted on the pavement. The first sign is 116 ms ahead of the crossing, the sign is repeated just before the zebra. There is a 40 km/h speed limit valid on a 6,5 km long part of the road including all the three critical points /M₁, M₂, M₃/. Speed limit can be explained by the physical characteristics of the road only in part. The surroundings of the zebra are hidden totally by the natural features of the terrain so that the driver can see the person crossing only when the pedestrian is already on the roadside.
Characteristics of Measuring Points $M_2$, $M_3$:

$M_2$, $M_3$ were situated approximately 2 kms after $M_1$. These two coherent measuring points, the first at the rising part /$M_2$/ and the second after the top on the descending part /$M_3$/ were equally approximately 150 m long. As far as visibility is concerned, the possible obstacle could not be seen - if it was not higher than the average height of a car /1,4 m/- on the descending part after the top even when the car is 26 ms away from the top of the gradient.

Procedure of Measuring at Point $M_1$:

Speed was measured quasi-continuously on the 150 m long part of the road before the zebra. The first datum represents the moment when the car reached the above-mentioned point. The last one means the speed of the car passing the zebra. Meanwhile our pretrained associate pretended a crossing aim while looking towards the opposite direction instead of towards the reaching up car. The appearance of the associate was fixed by pretraining in a moment that the car be out of stopping distance when the pedestrian reached the roadside. His speed and movement were determined so that the drivers be in total uncertainty whether the pedestrian started crossing or stayed on the roadside. Consequently the driver was free in deciding how to behave in driving: he could speed up anticipating that the pedestrian would look around before stepping on the road, with this attitude he could force passing the point before the pedestrian. The driver could speed down anticipating that the pedestrian would start crossing the road without looking around. For a well defined speed behaviour we had to choose the variables reflecting the dynamics of speeding. With this measuring method we gained an average of 5-6 discrete speed data per driver at this point.
Index 1 characteristic of their speed behaviour was determined by the relative difference between the highest and lowest speed. 

\[ Q = \frac{v_{\text{max}} - v_{\text{min}}}{v_{\text{max}}} \]

By means of the average of \( Q \) the drivers were divided into two groups / \( \bar{Q} = 7,5\% / : 

- Drivers braking whose rate of speed-changing was over the average of \( \bar{Q} \); 
- Drivers non-braking whose rate of speed-changing was under the average of \( \bar{Q} \).

The second index was gained from the data we got at the measuring point \( M_2 \). 

Procedure of Measuring at Point \( M_2 \): 

4 - 5 data per driver were gained at this point. The first one was characteristic of the spontaneous, relatively undisturbed road driving for the crossing was already 2 kms behind the drivers and the gradient was still 150 m ahead of them. The average data gained at this point produced the second index. 

- The driver is slow if his speed at this point is under the average / S/; \( \bar{x} = 66 \text{ km/h} \); 
- The driver is fast if his speed at this point is over the average / F/. 

We would like to emphasize that although the 40 km/h speed limit was valid at this part of the road all the drivers drove over the limit. This fact supports our conclusion that the participants' behaviour was not influenced by the normative rule but the results showed the individual speed-selection.

Ranging the first and last speed data before reaching the top of the gradient and those after, we gained a speed diagram per driver determined by these four data. Further indexes /3, 4/ expressing
the dynamics of drivers' speed changing were determined through these individual diagrams.

The third index was derived from the combinations of the differences between the above-mentioned four data. Aligning the differences of the sequential data \(v_2 - v_1; v_3 - v_2; v_4 - v_3\) we got an individual sign-combination consisting of three elements.

In conformity with the fact whether the drivers increased, decreased or did not change their speed between the measuring point might have involved signs "+", "-", or "0". Since symbol "0" never appeared, theoretically we could have gained \(2^3 = 8\) different sign-combinations we, however, did not get but two different ones in the whole experimental sample. These are as follows: "-", "+", "+" \(n=13\) and "-", "-", "+" \(n=12\). It seems that two different types of speeding behaviour could be identified.

The formal mathematical, statistical evidence of this is:

\[
P = \frac{(\frac{8}{2})(2^{25} - 2) + (\frac{8}{2})}{8^{25}} \approx \left(\frac{8}{2}\right) \left(\frac{1}{4}\right)^{25} \approx 3 \times 10^{-14} \text{ (!!!)}
\]

So, according to the third index the driver of "-", "+", "+" combination was designated as "anticipating". This combination can be described that the driver speeded down reaching up to a critical situation, in our case the top of the gradient, and from the top he began immediately a constant acceleration. This can surely be considered as an adequate behaviour since at the moment reaching the top these drivers could see clearly their possibilities for changing to the aptest speed.

The second group of the third index was called "over-braking". It was described by "- - +" combination. For these individuals kept braking during the whole critical situation. They only
started speeding up when this situation was over. According to the survey data this action could be derived from two different behaviours:

- they either arrived at such a high speed to the gradient that they had to brake so vigorously that braking effected their speed even on the descending slope;
- or they drove in such an "over careful", "timid" way that they started to increase speed only when they were out of every risk of the situation, so they speeded up only after the optimum moment.

By means of the 4th index we expressed that to what extent the driver increased his speed after the critical situation in comparison with the extent of his decreasing speed previously. The rise of the decreasing and increasing parts of the drivers' individual speed curve was compared to each other, this ratio is expressed by the index.

Schematical figure:

\[
T_i = \frac{\tan \alpha}{\tan \beta}
\]

In the sample observed \( T = 1.384 \)

By the average \( \bar{T} \) we divided the participants into two groups. Drivers were considered as "impulsive, vehement" in case of \( T_i \) being higher than \( \bar{T} \), and as "unimpulsive, balanced" in case of \( T_i \) being lower than \( \bar{T} \).
Groups within the four indexes are as follows:

Index 1:
- braking /B/
- non braking /NB/

Index 2:
- slow /S/
- fast /F/

Index 3:
- anticipating /A/
- over-braking /OB/

Index 4:
- impulsive /I/
- unimpulsive /UI/

Due to the dichotomised grouping we examined the correlation of these four indexes by the Fisher's "Exact probability test". The result are:

Indexes 1-2: \( p = 0.009 \), we found correlation between the characteristics of braking and slow behaviours as well as between non-braking and fast ones.

Indexes 1-3: \( p = 0.04 \), this shows that the braking and anticipating so as non-braking and over-braking characteristics correlate.

Indexes 1-4: \( p = 0.13 \), this shows a tendency of correlation between braking and unimpulsive as well as non-braking and impulsive. /Conventionally the 0.05 value of likelihood is generally not considered as conclusive we think, however, that the limited number of samples and the complexity of characteristics make the real correlation probable in this case/

Indexes 2-3: \( p = 0.0075 \), this shows correlation between slow and anticipating so as between fast and over-braking features.

Indexes 2-4: these indexes did not show correlation

Indexes 3-4: \( p = 0.025 \), there is correlation between anticipating and unimpulsive as well as between over-braking and impulsive characteristics.
Although we could not find any correlation between the indexes 2 and 4 we think that on the basis of the almost total structure of correlations of the other indexes two main groups of typical behaviour in critical situation can be separated:

I. Non-braking - fast - over-braking - impulsive;
II. Braking - slow - anticipating - unimpulsive.

Before starting to discuss the risk aspects of them we would like to call the attention to two above-mentioned facts:
- drivers classed into the "slow" group still drove at a higher speed than the 40 km/h speed-limit permitted;
- it is possible that the category "over-braking" covers two different but both extreme driving behaviour. One of them owing to driving at an extreme high speed and the other is due to an over-careful, irresolute driving manner.

It is easy to see that the above-mentioned two main groups of the typical behaviour forms can be appreciated differently from the point of view of risk even if this appreciation is based only on hypotheses and needs, therefore, further proving. Empirically it may be supposed that the second type has lower risk than the first one.

These two typical speed-behaviours can be described conceptually as follows:

I. In a free traffic stream when the situations are free from critical events the driver of the first type drives at a significantly higher speed than the average. This speed is so high that it must be decreased suddenly and considerably in order to conform appropriately to the given situation. Such a high speed may involve that in case of an unexpected obstacle the driver is ready to force the favourable outcome of a possible conflict situation by keeping his speed. After braking he speeds up suddenly making his driving style impulsive and fluctuating.
II. Drivers of this type choose a lower speed in a free traffic stream. It is to be emphasized, however, that this does not mean real slow driving but the choice of a speed maybe exceeding speed-limit, though, it conforms to the reliable speed given by road and traffic conditions. These drivers get ready for the possible risk of a situation when approaching a critical point. But in the moment when the possibility for driving on safely is clearly given they immediately increase their speed. Consequently, their speed behaviour is "smoother" significantly requiring less sudden change of speed.

Maybe these conclusions are trivial but they are supported by concrete measured data so can be considered as proved by quasi-experimental methods.

Types detailed above showed significant differences in the opinions on the causes of traffic accidents, in their relation to high-speeding, even in their opinion on traffic-partners. These differences will be presented in another paper if we have the possibility for it.
Within the framework of a study on the safety of one-way streets, we carried out a "before-and-after" evaluation of the effect of a change from two to one-way traffic. The street which was evaluated is a residential street (Sokolov Street), about 300 m. long, 3.5 m. wide, and only partially paved. The street attracts heavy pedestrian traffic, mainly children walking to and from school. Vehicle volume is low, about 800-900 vehicles per day. No accidents have been recorded on the street.

Traffic counts and behavioural measurements were made on Sokolov Street and on neighbouring streets and junctions in the potential influence zone of the change. The measurements included:

- Traffic counts -- automatic in mid-block as well as manual counts of movements in affected junctions and counts on Sokolov Street by direction and type of trip (local vs. through traffic)*.
- Speed measurements on Sokolov Street.
- Observations of pedestrian walking and crossing patterns.
- Encounters between vehicles and pedestrians walking along the road or crossing it.

An encounter was defined as an event where a pedestrian was present on the road when a vehicle was passing by. The encounters were classified into three categories: a close encounter with no apparent change of course by either pedestrian or vehicle; encounters where the driver was forced to take

* One aim of the change was to reduce the amount of through traffic.
evasive action (slowing, swerving); and encounters where an evasive action was taken by the pedestrian (side stepping, backing up).

All measurements and observations were performed both before and after the change from two to one-way. The main findings were:

- Vehicle volume on Sokolov Street did not change. The share of local trips (trips that started or ended in the street) remained the same.

- Traffic on the neighbouring street (which goes one way in the opposite direction), increased by 100%.

- Mean speeds on Sokolov Street increased from 34 to 39 km/h. The speed distribution moved to the right in the high speed range, and the number of speed offenders went up from 2% to 10%.

- After the change, 5% of the cars were observed driving the wrong way.

- Volume of walking and crossing pedestrians remained the same.

- The number of encounters remained similar. However, after the change to one-way, the ratio of encounters involving evasive actions by either the driver or the pedestrian increased from 9% to 30%.

In summary, though traffic and pedestrian volumes on Sokolov Street itself remained constant, it seems that the change from two to one-way of this residential street has caused a decrease in safety. This is demonstrated by the following observations:
The total amount of travel in the area increased.
- Speeds increased and there were more speed offenders.
- There was a substantial number of violations of the "do not enter" sign.
- There was an increase in the number of encounters between cars and pedestrians that forced an evasive action.
1. Introduction

The road traffic plays an essential role in providing for the needs of transportation in our modern society. No trip can be made without participating in one way or another into the road traffic system. The strongly increasing number of cars has involved a sharp increase of the number of traffic accidents during the sixties. In order to meet this growing traffic unsafety problem several measures were introduced like exacting higher standards of the technical equipment of cars, of the qualifications on getting a driver license and of the lay-out of roads and intersections. As a result since 1972 the number of traffic accidents is decreasing in spite of almost a doubling of the number of cars. Nevertheless the extent of the current traffic unsafety is still not acceptable because of the enormous human harm and economical damage. Since the major failures of the traffic system have been eliminated, the research methods, suitable for improving traffic safety, have to be more complex and refined. Furthermore, given the modern need for transportation, traffic unsafety cannot be tackled separately anymore without influencing the operational functioning of the traffic system. More and more a human-factors approach in research on traffic safety will be needed.

Because of their own responsibilities road-administrators will be interested first of all in improving the lay-out of roads and intersections. The gathering of accident or conflict figures has to be followed by a systematic observation and analysis of the whole traffic process.

In order to illustrate this approach some examples of research will be discussed emphasizing the decision-making element in the human information processing cycle of perception, interpretation, decision-making and handling in relation to the road environment and/or other road users (the actual behaviour versus the environment).

2. The functioning of local dual carriageway intersections

On the basis of an accident analysis (priority accidents on the second carriageway dominant, with locally well-known motorists frequently involved) and because of the relatively low traffic volumes on the main road (daily about 2000 vehicles) it was decided to reconstruct the rural intersection "St. Nicolaasga" from a large-scale dual carriageway inter-
section with a wide median to a simple priority intersection with only marked left-turn lanes on the main road.

In a before- and after-study several aspects of roadusers' behaviour were analysed in detail, like speed on the main road, the way of entering or leaving the main road (with and without separate traffic lanes) and the negotiation of the intersection by traffic from the minor road (Hofstra, 1984). By means of specific video-recordings also an inventory of the looking behaviour of drivers (head-movements) was conducted in order to check whether the reconstruction would result in a better surveyability and a more uniform crossing of the junction.

The reconstruction resulted into a reduction of first head-movements in the wrong direction (firstly to the right) from 12 to 8% and a sharp reduction of the number of head movements both before and during crossing the main road (from 68 to 16% of crossing motorists). In the after period most head-movements took place in the road section prior to the intersection. The effect of not making head-movements during the crossing indicates a more uniform decision making process and a greater certainty (once a decision has been made, it is checked less frequently). In the before period 12 percent of the roadusers is looking also to the left when approaching and crossing the second carriageway, which is redundant in fact. In conclusion in the case of low traffic volumes the simple (and cheap) solution of an intersection with only painted left-turn lanes appears to function better than a large scale dual carriageway intersection.

3. Road design and bicycle traffic

In The Netherlands in urban areas the bicycle contributes substantially to the total demand on transport. Because of its attractive qualities like milieu-kindly, healthy and cheap, the bicycle has gained popularity again during the last years. To stimulate the use of the bicycle some years ago the central government had designed and constructed two demonstration cycle-routes at The Hague and Tilburg, two cities in The Netherlands. Specific road design elements like speed control humps, lane constrictions, cobble pavement, etc. were applied in an experimental way. For the greater part their effects on roaduser behaviour and road safety were unknown. The experimental character of this demonstration project enabled systematic research into the functioning of different types of solutions for the same kind of problems.

By means of some well-chosen design elements like lane constrictions and humps it appears possible to control the behaviour of car drivers when intersecting a cycle-track (with priority for bicyclists). Not only these elements do reduce the mean approach speed of cars, but also the minimum speed is reached a few metres prior to the cycle-track instead of on or after the cycle-track for control locations without special provisions, an example of which is given in Fig. 1a. This is one of the indications that car drivers at the experimental locations pay more attention to cycle-track and also to its users, as is illustrated by conflict data, see Fig. 1b (Van der Horst, 1984).
The evaluation method used, i.e. an objective quantification of interacting behaviour between road users from video-recordings (Van der Horst, 1982), enables not only an objective counting of traffic conflicts but also a detailed analysis of the preceding process.

Fig. 1a Speed profiles (with standard-deviation) of crossing cars involved in interactions with bicyclists for an experimental location (H1) and control location (H11).

Fig. 1b Risk-indices (number of conflicts/exposure) based on different minimum TTC (time-to-collision) values.

An design parameter in applying a speed control hump is the distance between the hump and the element it is intended for (here the cycle-track). A comparison of locations where this distance was different (between 0 and 5 m), resulted in a preference for a hump at the beginning of a plateau at a distance of about 4.5 m on either side of the cycle-track.

Another important element in the behaviour of bicyclists concerns the gap-acceptance when intersecting an urban arterial road. Which gap in a traffic stream do bicyclists accept for crossing and what is the influence of the lay-out of the main road, the type of manoeuvre, one or two-way traffic, etc. After the cyclist's decision to accept a gap the consequences have to be evaluated, how is the crossing passing in relation to the oncoming car? For this study video-material was used, available from another demonstration project, viz. "the demonstration project on redesigning urban areas at Eindhoven and Rijswijk", also two cities in The Netherlands (Van der Horst and Ten Broeke, 1984). At two locations the behaviour of cyclists was analysed before and after a reconstruction of the lay-out of the Leenderweg at Eindhoven for two types of manoeuvres, a left-turn by cyclists from the cycle-track along the main road (E1) and a crossing from the minor-road (E2), see Fig. 2.
Before the reconstruction the main road consisted of a carriageway of 2 x 4.6 m with a dotted middle line. In the after situation the carriageway was reduced to 2 x 3.6 m divided by a painted median with a width of 2 m, completed with a refuge and side-line markings in order to facilitate the crossing for cyclists and pedestrians. For the description of the decision-making behaviour the critical gap ($t_{crit}$) is often used, defined as the intersecting point of the cumulative distribution of the rejected gaps greater than a certain gap length $t$ and the cumulative distribution of accepted gaps less than $t$, see Fig. 3. For the critical gap the probability of rejecting or accepting is the same. Fig. 4 gives the effect of lay-out and the first or second traffic stream. The central refuge zone in the "after" situation reduces the critical gap values, for the first as well as for the second traffic stream. Also the mean crossing time is much lower after the reconstruction.

In order to indicate how "risky" a crossing manoeuvre is, a division of the accepted gap into manoeuvring time and remaining-time (RET) is made. RET is something like the PET measure (Post-encroachment-time), the time-difference between the moment the cyclist has left the path of the oncoming car and the moment the car reaches this leaving point. The lower this RET value the more risk cyclists have taken by accepting this gap. For example the mean RET values "before" and "after" do not differ (Fig. 5). However, for the second stream the probability on very small RET values is significantly lower in the after period. Especially for this crossing the reconstruction was made. Bicyclists are crossing faster the Leenderweg (less delay) combined with a lower risk.
Fig. 3a Cumulative distributions of rejected and accepted gaps by bicyclists for the first traffic stream, critical gap = 7.2 s.

Fig. 3b Idem, for the second traffic-stream, critical gap 5.9 s.

Fig. 4 Critical gap dependent on type of lay-out (BEFORE and AFTER) and the first or second traffic stream to be crossed, type of manoeuvre E1 (left-turn from cycle-track along main road).

Fig. 5 Mean remaining time (RET) and proportion of small RET times before and after reconstruction.
4. Drivers' decision making in relation to the yellow-timing of traffic signals

At signalized intersections the task of the road users with respect to other traffic is simplified substantially. However, the road user is charged with other tasks, for example in relation to the traffic signals. An important behavioural aspect consists of the decision-making for stopping or non-stopping at the moment the signal changes from green to yellow. Factors which may influence the decision making process will relate to, among others: the drivers' attitude, the amount of predictability of the situation, an estimate of the consequences of not stopping (the chance of running red, of a conflict with intersecting traffic, of getting a fine) and an estimate of the consequences of stopping (discomfort, waiting-time, the chance of a rear-end conflict). Weighing these factors will also involve the drivers' estimates of the required deceleration on the basis of speed and distance to stop-line, the duration of the yellow phase and the all-red period. Also the behaviour of other road users may influence the decision making.

Especially the duration of yellow-time and all-red time can be influenced directly by the road-administrator, besides of course the type of control strategy which is used. As an example effects of the yellow-time will be discussed in some more detail.

From a review of the extensive literature about this topic it appeared that an one second extension of the current values in The Netherlands (3 s yellow for 50 km/h intersections and 4 s yellow for 80 km/h intersections) would optimally adapt to what normally might be expected from car drivers and to what maximally can be achieved under poor circumstances (Van der Horst and Godthelp, 1982). This measure should reduce the number of run-red offences considerably. Furthermore a more uniform decision-making behaviour might also benefit to road-safety. Because the system is better adapted to "normal" behaviour, measures directed to enforcement might be much more effective. However, most of the research referred to isolated intersections or to rather short periods of habitation. Therefore a field experiment with an extension of the yellow time was conducted within a whole area, rather isolated from through traffic and for a period of at least one year. By means of a "before- and after" study the behaviour of car drivers has been evaluated from time-lapse video-recordings (Van der Horst and Wilmink, 1986). First of all it has been checked whether or not the extension of the yellow time had reduced the number of run-red offences. After one year the yellow-time extension with one second appears to half this number, as well related to the total number of vehicles (from 1.1 to 0.5%) as related to the number of deciding vehicles, non-stopping and first-stopping cars after the beginning of yellow (from 13.4 to 6.7%). In order to describe the decision-making behaviour properly, the stopping drivers have also to be involved. By this the probability of stopping can be calculated, for example as a function of the distance to the stop-line at the moment the yellow signal is switched on. However, a better description is given by the probability of stopping as a function of the potential time to stop-line (TTS), taking into account the individual initial approach speed of each vehicle and assuming vehicles will continue with a constant speed. Fig. 6 gives the results after a log-linear model fit. A small shift of 0.17 s is present. This small adaptation of drivers' behaviour does not change anymore after a period of six months.
An interesting effect of traffic control strategy on drivers’ decision-making behaviour appears when comparing these results with data from the literature (Fig. 7). All sets of data, except one, are based on field studies. Mahalel et al. (1985) conducted a laboratory experiment. A remarkable one second shift exists between a vehicle-actuated versus a fixed-time control strategy.

Fig. 6 Probability of stopping as a function of the time to stop-line (TTS) at the beginning of yellow.

Fig. 7 Probability of stopping as a function of the potential time to stop-line (TTS) at the beginning of yellow. Van der Horst et al. (1985) and Sheffi and Mahmassani (1981) for a vehicle-actuated versus a fixed-time control strategy (Williams (1977), Mahalel et al. (1985) and Hulscher (1984)).
Evidently a vehicle-actuated control leads to a shift in the criterion drivers use. In an earlier stage of the approach process drivers decide to proceed. The characteristics of the decision process itself are not different for both types of control, i.e. the slopes of the curves from the field studies are the same. The different slope of the curve of Mahalel et al. (1985) might indicate a somewhat deviant behaviour in laboratory circumstances.

5. Final remarks

The given research examples illustrate how the functioning of specific road elements can be evaluated in terms of resulting behaviour of road users under normal conditions instead of in terms of the traffic unsafety itself. In this approach the emphasis was put on drivers' decision-making. Together with the phases of perceiving and processing of information (for example relating with visibility, conspicuity, recognizability and comprehensibility of all kind of information-carriers in road traffic) the decision-making phase is an important one in the whole traffic process and strongly effected by the road users possibilities and limitations. Because of the dynamic nature of this process a description by time related measures such as TTC, GAP, RET or PET, TTS, etc. is inevitable, especially for a better understanding about how road users are handling critical traffic situations.

6. References


III. TRAFFIC CONFLICT TECHNIQUES AND THEIR DEVELOPMENT

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Origin, Validation and Implementation of the Traffic Conflict Technique (TCT) in the U.S.

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Origin of the TCT

It would be presumptuous for an individual or agency to claim total credit for development of what is generally referred to today as the TCT. Any engineer, researcher, or technician who has had the responsibility of observing a known hazardous highway location for purposes of identifying problems has, in a sense, performed a traffic conflict study.

The problem, however, with simply observing a spot location in order to detect problems without the use of observation aids is that the human mind cannot always sort, categorize, measure and count what is seen with the eye. The solution, therefore, is to predefine and order observation based upon known characteristics of motorized, nonmotorized and pedestrian traffic so that the objective recording and synthesizing of data can be accomplished.

Thus, the TCT is nothing more than a set of definitions that are based upon the most common multi-vehicle interactions, particularly those that can be paired with corresponding accident types. It is usually implied in the definitions that the observed traffic interactions demonstrate high observer reliability; that is, with proper training, most individuals should be able to observe and record these interactions in nearly the same way. The definitions further imply that the observed traffic interactions are repeatable; that is, subsequent events by type will continue to occur in the same way under similar conditions.

In 1968, two researchers with the General Motor's Research Laboratories were assigned the task of observing traffic at intersections to see if differences could be detected in the way General Motor's vehicles performed relative to other manufacturer's products. While they could see nothing special about the way General Motor's vehicles performed, it was evident that all vehicles, regardless of manufacturer's nameplate, did take evasive action in much the same way.
At first, it was hypothesized that near misses, or, what we would today call "serious" conflicts, might in some way constitute an indicator of potential accidents. However, after observing traffic at many locations under high volume, high speed conditions, it was concluded that, like accidents, near misses were relatively rare events. But, there still occurred large numbers of events that were characterized by either brake light indications or swerving maneuvers.

Thus, a basic definition was posed that these traffic events were "conflicts" in the flow of traffic and that, therefore, a traffic conflict was an evasive action, characterized by brake light indications or swerving, change of path maneuvers that one vehicle took to avoid a possible impending collision with another vehicle.

It is important to note that a conflict could only be recorded if both the offending and the offended vehicles could be seen, thus eliminating normal braking for traffic control devices.

The basic definition was, then, broken down into 24 sub-definitions, each of which corresponded to an existing accident type. Using these definitions, a sampling approach to gathering data was tested and field procedures were developed as a result of trial and error experimentation.

What remained was to develop field data forms, conduct a number of specific counts utilizing all the procedures and discuss this potential new tool with local and State highway representatives. The primary argument was that the conventional use of accident data as a measure of performance is, in a sense, archaic and depends upon system failure (i.e., accident histories) to provide data with which to correct safety hazards. It was further argued that the use of the TCT might enable highway personnel to implement improvements before accidents occurred and that, in time, a more formal study might demonstrate that traffic conflicts are a surrogate for accidents.

Enough interest was generated as a result of these first studies that a paper was presented at the Transportation Research Board in 1968. This, in turn, was followed by the conduct of a 3-State demonstration project sponsored by the Federal Highway Administration (FHWA) and provided the impetus for many small underfunded research studies, many of which were subsequently determined to be flawed in design.

It became clear that there were two basic applications of the TCT:

1. As a diagnostic tool for identifying operational problems.
2. As a safety evaluation tool for predicting accident experience.
Further, it was now recognized that the various conflict types would result in significantly different accident/conflict ratios and that larger, more heavily funded studies were necessary. At this point in the mid seventies, the only application being made of the TCT was for diagnostic purposes.

Interest remained high, however, and in 1978 the Transportation Research Board, through its National Cooperative Highway Research Program (NCHRP) initiated a study to develop a standardized set of operational definitions and procedures for measuring traffic conflicts. The research included the proposal of various candidate TCT definitions and the conduct of extensive comparative field tests. Over 9 weeks of field data were collected using 17 observers trained for this specific purpose. Analysis of the data led to a recommended set of 12 definitions, all of which demonstrated very high observer reliability, and which were similar to the original GM definitions. Results of the study were published in 1980 as NCHRP Report 219, Application of Traffic Conflict Analysis at Intersections.

By this time, interest in the TCT as an operational tool in the U.S. began to decrease due to lack of knowledge of the conflict/accident relationship. It was obvious that if the TCT was to survive, a validation study was necessary as well as the development of a training package that included how to interpret conflict data. It should be noted that the original GM work and most studies that followed did not produce acceptable conflict/accident ratios, so the user community never quite knew how to determine when a conflict count indicated that a potential traffic problem was serious enough to warrant remedial action.

In summary, the early GM work provided much of the conceptual basis for the development of conflict techniques in other countries. Each member country of the International Committee on the Traffic Conflict Technique (ICTCT) that has been influenced by the GM work has produced their own definitions and technical refinements. Some of the TCT's used by others are a radical departure from the GM approach; however, it can generally be said of each variation that regardless of the definitions adopted or the procedures utilized to count and interpret data, the overriding purpose of the technique is the estimation, before accidents occur, of the degree of existing hazard.

Validation of the TCT

This discussion is offered from the perspective of an attempt to implement the TCT on a large scale among city, county and State highway personnel in the U.S.

The most significant obstacle to past attempts to implement the TCT in the U.S. was the absence of research that established a positive relationship between conflicts and accidents. There was much interest in the TCT in the
seventies, but despite the fact that its use for diagnostic purposes was successfully demonstrated, highway agencies were reluctant to commit funds for safety and operational improvements on the basis of vehicle interactions that were only theoretically related to accidents. In the U.S., accident data is and probably always will be the ultimate measure of safety performance.

As a result, the TCT is not used operationally on a widespread basis. Recent use has been confined to specific research studies where it was obvious that accident data was either not available or would not provide a sensitive enough measure.

In an effort to deal with this problem, the study Relationships Between Traffic Conflicts and Accidents was conducted and published in 1985. The purpose of this study was to establish relationships between traffic conflicts and accidents, and to identify expected and abnormal conflict rates given various circumstances. The data for this study were collected during the summer of 1982 at 46 intersections in the city of Kansas City, Missouri, and was limited to daytime and weekday traffic, and to dry pavement conditions. The extent to which the findings can be extended to other conditions is not known, but based on general safety research, accident/conflict ratios may be higher at night and when the pavement is wet or icy.

The 46 intersections studied were stratified as follows:

1. Signalized, high volume,
2. Signalized, medium volume,
3. Unsignalized, medium volume,
4. Unsignalized low volume.

Each intersection was observed for four days, thus providing four replicate data sets. The conflict definitions tested in National Cooperative Highway Research Program Report 219 were used. Accident data were obtained for each of the 46 intersections for the years 1979, 1980, and 1981. Data for 1982 was acquired for eight randomly selected intersections for use in testing the prediction methodology. All accidents were classified according to whether or not they were conflict-related and met the TCT data collection time, and pavement condition requirements.

There were 24 specific conclusions to this study, but those most likely to be referred to are:

"The proper use of conflicts is to estimate an expected rate of accidents, as opposed to predicting the actual number that might occur in a particular year. Accident data fluctuate greatly from year to year; the best one should expect is to be able to accurately and precisely estimate the average (expected) value."

and
"Overall, traffic conflicts of certain types are, indeed, good surrogates of accidents in that they produce estimates of average accident rates nearly as accurate, and just as precise, as those produced from historical accident data. Therefore, if there are insufficient accident data to produce an estimate, a TCT study should be very helpful."

It is probably safe to say that safety evaluation methodology employed in the analysis of hazardous highway locations in the U.S. is in many instances nonexistent, and, at best, not well understood. Therefore, many highway personnel who have safety evaluation responsibilities will likely only accept simple answers to the TCT validity question if there is to be widespread acceptance of the TCT.

The conclusions that the user community is looking for are not those stated above with their references to estimates of average accident rates, but one that might simply state:

Research has shown that traffic conflicts are good surrogates for accidents.

Thus, while the credibility issue has been addressed to some extent (i.e., under certain conditions certain conflict types are good surrogates), those who would implement the TCT are faced with at least two significant new problems:

1. Since prediction methodology forms the basis of the accident/conflict relationships, then prediction methodology itself, as well as TCT counting and analysis methodology must be a part of any training program. This will no doubt complicate the Traffic Conflict training task by introducing controversial, seldom used evaluation procedures.

2. Because the accident/conflict relationships must be used only within the context of the conditions under which they were derived, the task of translating research results into tables and/or other user oriented aids will require some developmental work along with the training package assembly. The following study conclusion illustrates this point:

"If a potential TCT user determines that his conflict rates and variances differ substantially from those obtained in the midwest U.S.A. during this study, he will have to adjust the values given in Tables 3 through 6. The procedure is described in Volume 2, and involves the use of a few simple equations and interpolating from an available statistical table."
Due to these and other potential problem areas, the shift from informal evaluation procedures utilizing only accident data to a more sophisticated prediction methodology that can employ both Traffic Conflict and accident data on a large scale among the user community will be difficult to achieve. Nonetheless, the commitments have been made to attempt this task. It is not likely that funding will be available for additional research activities and once the current training activities are completed, Federal funding for implementation will probably not be available. It will be at least three years before the level of interest in the U.S. can be measured and probably five or more years before the practicality of operational use by various highway agencies can be assessed.

Implementation of the TCT

The practical application of the TCT in the U.S. on a large scale will be attempted according to the following schedule:


Phase 2, October 1988 - October 1989 - Inclusion of a 3-day FHWA sponsored course for interested highway agencies as part of the annual training program.

Phase 3, beginning October 1989 - Establishment of a centralized source to promote and supply information on successful U.S. applications and other techniques, especially severity rating concepts developed through the ICTCT.

The objective of the training contract is to develop a course to train state and local highway engineers and technicians to:

1. Conduct traffic conflict studies,
2. Train others to be traffic conflict observers,
3. Analyze and interpret traffic conflict data.

The contractor will be required to develop an Observer's Manual and Engineer's Guide (two separate publications) as well as a 3-day training course outline which will use these two publications as the primary training materials. The publications will incorporate the research work described in NCHRP Report 219, Application of Traffic Conflict Analysis at Intersections and FHWA Research Report, Relationships Between Traffic Conflicts and Accidents.

The Engineer's Guide will include how to train observers, when and where to conduct conflict studies, type data to collect, data analysis and interpretation procedures, TCT applications, and a description of the procedures necessary for normalizing conflicts data to reflect the highway and/or driver characteristics of a particular geographical area.
The 3-day training course outline is to include general information, course objectives, agenda and schedule and is to be structured so that personnel with only a basic knowledge of the TCT can arrange for and present the course.

As a part of the contract, two 3-day pilot presentations for up to 25 participants each will be held. The purpose of the pilot presentations will be to evaluate the course materials and procedures so that revisions can be made prior to the offering of this course as part of FHWA's annual training program.

Following the completion of the two year contractual effort, the course will be listed in the FHWA annual training program. The offering of this course beyond one year will depend upon the interest generated through regular promotional efforts such as flyers and announcements in newsletter and technical magazines.

Obviously, the major emphasis in this approach to the practical application of the TCT is to introduce an easily understood, uncomplicated version of the TCT so that it might be employed on a large scale. If widespread interest is generated, the training effort will be followed by the establishment of a centralized U.S. source for the dissemination and exchange of information regarding practices and experience in the use of the TCT.

Through this source (probably FHWA) information resulting from ICTCT activities would be distributed and users encouraged to experiment, for example, with various severity rating procedures.

Thus, the work started in the late sixties by two individuals who had no prior experience in the highway safety area and who, by 1972, were no longer involved with the TCT, has significantly affected the way many of us think about safety evaluation methodology. Traffic Conflicts are, by far, the most promising of the potential safety performance measures to be considered as a surrogate for accidents. However, the extent to which the TCT becomes an operational tool with widespread application by highway agencies at the local and State level is yet to be determined.


THE DEVELOPMENT OF THE SWEDISH TRAFFIC CONFLICT TECHNIQUE

by

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The Development of the Swedish Traffic Conflict Technique

Presented at the seminar on "Traffic conflicts and other intermediate measures in safety evaluation". Budapest september 8-10, 1986.

The work at our department to develop a traffic conflict technique started in 1973 and a technique for operational use was specified in 1974. Since then, the technique has been modified in different aspects and is still under further development. My purpose is to present some of the essential motives for the steps we have taken in the past, and those that we necessarily have to take in the future.

Dévelopment of the definition of a serious conflict.

To find the first definition we looked for a limit where even a well trained road-user had no other choice than doing his best to avoid the accident by braking or swerving (the point of no return).

This limit was found to be 1,5 seconds from the starting of an evasive manoeuvre until the accident would have occurred, if there had been no evasive actions.

For this criterion limit, we looked at critical situations in which skilful drivers (viz. taxi drivers) performed evasive manoeuvres. Here we found the time limit 1,5 seconds. Below this limit the manoeuvres no longer were examples of "tough" or "tactical" driving, but were made only to avoid an accident.

Most serious conflicts according to this definition take place with a certain suddenness, which makes it possible to use human observers for registering conflicts in the field.

Our definition was afterwards confirmed in a study where we did interviews with the involved road-users just after the conflict accrued. If the Time to Accident (TA) was more than 1,5 seconds, then few of the interviewed persons could remind themselves of that specific situation as a risk situation. This definition worked very good for several years in many research projects and in our first validation project. During these years we only worked at intersections with a very homogeneous speed distribution. When taking the step out to the highways, we immediately found that the limit between serious conflicts and other situations needed to be related to the Conflict Speed (CS). The distribution we chose was the distribution of a personal car braking on wet asphalt.
This means that we have broadened the definition rather than changing it.

Development of Validation

Since conflicts techniques often are very pretentious we need to show a valid correlation between conflicts and accidents. Other behavioural techniques with more farfetched definitions do not need to show its relation to accident even if they are used as a accident predicting method.

If you think that your conflict data are more reliable than accident data, at least in some aspects, then it’s a great problem if you are constrained to use police reported accidents as the key.

Our second big validation project, still ongoing, shows that conflicts gives a better estimation (smaller variance) of the accident ratio than police reported accident data do, if the accident frequency is low. In Car-Pedestrian situations e.g. conflict studies of one day give better estimation than one year of accident data as long as the frequency is below five accidents per year.

This indicates that we need better accident data before any radical improvement in this area is possible.
From a theoretical point of view we believe that the best conversion factors will be obtained through a determination in two steps:

1) to determine the probability of each conflict leading to an accident

2) to determine the probability of each accident leading to personal injury.

This means that we need to have information about every collision in the intersection during a long time. This in turn calls for some kind of automatic data-collecting method that can be running for weeks.

Development of the use of our conflict technique:

In the beginning we used conflict studies only as a accident substitute using only the advantage of quick result and a high number of data. We worked in intersections with lots of conflicts and then it was good enough just to count the conflicts without describing each conflict in detail.

Another very important use of conflicts is when doing before and after studies since you can avoid the problem with regression to the mean, a problem that always occur if you use accidents both for selection and for the evaluation of an effect of a rebuilding.

While working in areas with few conflicts per day, we found that the observer was capable to record more details about each conflict. This increased the quality of the diagnostical part of the conflict studies. This is an area where we have great expectations of success. We might even get the same or better results than you get from "traffic accident case-studies". For this reason we need to do further development on systematization of the causes of each conflict and what countermeasures that could hinder this conflict to occur. We also need to develop the technique of interviewing the involved road-users in a conflict.

Development of the technique in the future

Next big step for the conflict technique will probably be when the image-processing by computer is capable to work in real time. Then we will be able to select situations that should be analyzed afterwards. We should also use image-processing as the key for manual observation.
1. Introduction

Road accidents constitute an important negative aspect of the quality of the traffic process. A number of different approaches are employed to try and reduce the extent of this problem. In the past it was attempted to blame one single main cause in the traffic process as being responsible for road accident occurring. Road accidents are generally, however, the result of a chain of events. During recent years one can observe a movement towards a practical problem-orientated, and more integral way of thinking and operating. This (dynamic) system approach is being made increasingly applicable for the analysis and control of road safety.

There are two central matters in this approach:
- process analysis in phases aimed at searching for the critical chain of events, or rather the critical chain of risk factors;
- control analysis of the process phases, aimed at the consideration of possible measures until the most effective combination of measures has been found.

The pre-crash phase of accidents nearly always escapes the researcher's observations. This hinders the analysis of road safety. Historical data on accidents that have already occurred is often used. One tries to explain their occurrence using reconstructions. Such reconstructions are only partially possible because the available information about the accidents is incomplete and subjective.

An alternative to this method is to study traffic behaviour, and especially that behaviour which is considered to be dangerous. The most widely used is the study of conflict behaviour. The assumption is that many accidents will occur in those situations where a great number of conflicts occur. The number of registered conflicts is often used as an indicator of road safety. When analysing conflict behaviour it is also of importance to pay attention to the difference as well as the agreement between the numbers of accidents and conflicts. When does a conflict result in an accident? When can an accident be avoided? In other words, which aspects of behaviour under which circumstances determine the severity of a conflict? The conflict is not only used as an indicator of safety but moreover as an unit of analysis for safety analysis in explaining the safety situation. Which behaviour results in which conflicts and given a particular conflict, what is the chance of an accident?
2. Conflict analysis

Conflict behaviour is a type of risky traffic behaviour. We talk of risky traffic behaviour or traffic risk if that traffic behaviour occurs in a situation where it can have negative consequences, particularly injury.

The main consideration with risk is the choice of the road user from a number of behaviour alternatives in relation to the behaviour of other road users. How great is the chance that certain types of behaviour result in an undesirable chain of events that ultimately lead to injury or material damage? How do conscious and unconscious choices in behaviour come about in these situations? Risk control is linked to the control of such choices in behaviour. We can study the various types of behaviour which occur in reality in combination with the behaviour of other road users and attempt to trace which combinations of behaviour lead to fatal events. Such combinations may be described as conflicts. The greater the chance of a serious accident, the more serious and therefore dangerous the conflict will be.

The essence of the usefulness of the conflict method does not lie, as is often erroneously maintained, in the forecasting of accidents but in pinpointing dangerous situations. It is often unrealistic to forecast the number of accidents because, statistically speaking, accidents are rare. The point is to estimate the chance of an accident and to indicate which types of observed conflict behaviour contribute to an increase in the chance of accidents and their severity. There is, therefore, no fundamental difference between general road safety research and conflict analysis as far as confirming a theory of risky traffic behaviour is concerned.

3. The DOCTOR Technique

The conflict method is already being used in a number of countries in a wide variety of real life situations. Under the auspices of the ICTCT (International Committee on Traffic Conflicts Techniques) an international calibration study took place in Malmö, Sweden in 1983 in order to compare the then existing techniques, using individual observers (Grayson [ed.], 1984). A comparison with objective data, obtained from a quantitative analysis from video (Van der Horst, 1984), indicated that observers severity scores were mainly correlated with time-to-collision and conflict type. On the basis of the information and experience, as gained from this calibration study as well as from earlier applications of other conflict observation techniques in the Netherlands (Güttinger, 1980; Van der Horst, 1984; Hyden, 1983) the Dutch technique DOCTOR was developed by the Institute for Road Safety Research SWOV and the TNO Institute for Perception. This development was started because most of the existing techniques were designed for local situations which often differ from those in the Netherlands. With DOCTOR it is attempted to combine the advantages of the other techniques, especially with respect to the Dutch circumstances. Our aim was to develop a technique which can be used under many circumstances, is methodologically sound, and which can be applied in a controlled way.

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1DOCTOR: Dutch Objective Technique for Operation and Research.
Because of the problems of a large scale application of an objective measuring technique (quantitative analysis of video tapes [see Van der Horst, 1982]) the use of observers has to be accepted. Observers in the field are scoring certain traffic situations as a conflict according to a standardised procedure. The DOCTOR observation sheet is given in the Appendix.

In DOCTOR a conflict is defined as a critical traffic situation in which two (or more) road users approach each other in such a way that a collision threatens, with a realistic chance of injury or material damage if their course and speed remain unaltered. If the available space for manoeuvre is less than that needed for normal reaction there is a critical traffic situation. In order to classify the danger, involved in a conflict situation, the severity of a conflict is scored (on a scale from 1-5), considering a) the probability of a collision and b) the extent of the consequences if a collision had occurred. In the following these two dimensions will be discussed in some more details.

**Probability of a collision**

The probability of a collision is determined by the "time-to-collision" (TTC) and/or the "post encroachment time" (PET). The TTC is defined as the time remaining until two road users on a collision course will collide if course and speed remain unaltered. As long as the road users are on a collision course TTC is a continuous function of time, an example is given in Fig. 1. The lowest value of TTC which is attained during the approaching process is indicated as TTC\text{min}. TTC\text{min} describes the ultimate result and is a good indicator of the maximum probability of collision which can occur at an encounter. The lower the TTC\text{min}, the greater the chance of collision. In urban areas, generally speaking, only a TTC\text{min} of less than 1.5 s(conds) constitutes a potentially dangerous situation.

![Fig. 1 Example of a TTC curve as a function of time (lower part) and the difference between TTC at the moment an evasive action (braking, see upper part, $V =$ speed) is initiated and the minimum TTC value.](image-url)
The concept of TTC requires a collision course. However in cases that road users just miss each other at high speed without considerable course or speed alterations there is, strictly speaking, no collision course. Still there is a realistic chance of a collision under such circumstances, i.e. a slight disturbance of the process will easily result in a collision. The PET provides a measure for this. It is defined as the time between the moment that the first road user leaves the path of the second and the moment that the second reaches the path of the first (Fig. 2). The PET consists of just one value which indicates the extent to which they missed each other after the intersection. Here also applies: the lower the PET the more likely a collision would have been. In general only PET values inside built-up areas less than 1 s are experienced as possibly critical. In DOCTOR the observers give their estimate of TTCmin or PET on the observation sheet (Appendix).

![Diagram](image)

**Fig. 2** Definition of PET; post-encroachment-time.

**Extent of the consequences**
The extent of the consequences if a collision had occurred (injury and/or material damage) is mainly dependent on the potential collision energy and the vulnerability of the road users involved. Factors which influence these aspects are: the mutual difference in speed, the available and necessary space for manoeuvre, the angle of approach, the type of road users, etc. The mass and manoeuvrability of the vehicles are the most determinant. In order to estimate the extent of the consequences in the case of a (hypothetical) collision, a comparison must be made between the space for manoeuvre normally necessary to be able to react during such encounters (e.g. anticipatory braking with a normal, comfortable deceleration) and the space for manoeuvre actually available at the moment evasive action is initiated. In critical situations this difference will often be negative. The size of this difference together with the types of road users (among others: mass and vulnerability) determine the extent of the consequences. The greater the difference between normal and available space for manoeuvre the more drastic and maybe more complex (swerving as well as braking) the evasive action has to be. Without (extra) reaction from at least one of those involved, a collision will be the result.

To obtain an as unambiguous estimate as possible of the injury severity and for additional information for analysis and diagnosis, several aspects of the conflict are scored or registered on the observation sheet. First it is
important to know the type of road users involved. There are great differences in mass, manoeuvrability, reaction speed, effectiveness of evasive action (required space for manoeuvre) between a bicycle and a car. Given a certain speed and distance, the difference between available and normally needed space for manoeuvring will therefore be less when a cyclist approaches the flank of a car than when the car approaches the cyclist. Furthermore an estimate of speeds (usually at the onset of evasive action) and the type of evasive action are recorded (evasive action or not, controlled or uncontrolled, braking, accelerating, swerving).

The DOCTOR observation form (Appendix) shows how the above-mentioned aspects are recorded.

Observers and training
In order to guarantee systematic and controlled observations it is essential that:
- the subjectivity of observers is reduced by selection and training, and
- a clear description of the method is given in a manual.

The DOCTOR manual (Kraay, et al., 1986) contains a general, theoretical part and a series of practical examples. This latter part, together with video tapes (instruction-, training-, and testtape) of 116 traffic situations is meant to provide concrete insight in the application of the technique and the method of scoring conflicts. Training in the Dutch DOCTOR technique lasts one week and consists of training in the field as well as video training. The observations in the field training are discussed collectively afterwards and evaluated using video tapes recorded simultaneously. The observers are taught which criteria are important for scoring conflicts and selecting severity.

The experience in training different groups of observers is that a selection of candidates is necessary, because of the complex task which is demanded. However, exact criteria for selection can not be given yet.

Analysis and diagnosis
Together with the general data for the locations being researched (road and traffic characteristics such as geometry, road markings, traffic signs, traffic composition, traffic volumes, speeds etc.) the data gathered on the DOCTOR observation form constitute the basis for further analysis.

The way in which the traffic behaviour is analysed depends on the research problem. The ultimate result is a presentation of which forms of unsafe traffic behaviour occur under which circumstances and to what extent. Based on this information a diagnosis can be given. Sometimes measures can be determined, based on existing knowledge and experience. Sometimes it can be derived which kind of a more specific in depth study of road users' behaviour will be needed.

4. Initial evaluation

The first application of the DOCTOR technique took place in Trautenfels, Austria, at a signalised rural intersection within the framework of a second ICTCT calibration study (Kraay & Van der Horst, 1985).
The design of the Trautenfels study made it possible to carry out an initial evaluation of the field scores using the DOCTOR technique. During the three and a half days of observations a total of 167 conflicts were registered by one or more of the six participating teams. The Dutch team, consisting of two observers, recorded the highest number (78).

Afterwards all 167 conflicts were again reviewed from video by the authors. As a result of this second judgement from video 86% were regarded as a 'rightly scored conflict' (Table I). The 11 conflicts incorrectly detected ('false alarm') all had a severity score of 1. This is therefore a question of criteria on the borderline of being a conflict or not.

<table>
<thead>
<tr>
<th>DOCTOR field scores</th>
<th>Conflict</th>
<th>No Conflict</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Judgement from video</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conflict</td>
<td>66</td>
<td>12</td>
<td>78</td>
</tr>
<tr>
<td>No conflict</td>
<td>11</td>
<td>75</td>
<td>86</td>
</tr>
<tr>
<td>Not possible from video</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td>89</td>
<td>167</td>
</tr>
</tbody>
</table>

Of those conflicts scored by at least one other team (but not by the Dutch team) there were 12 (15%) which by examining the video tapes should have been counted as conflicts. The severity distribution of these conflicts was exactly the same as that of the total number of conflicts. These situations had apparently been missed in the field. A further comparison with quantitative data obtained from the video tapes and with the results of other teams can be found in Oppe (1986).

5. Final remarks

The conflict observation method is being used in the Netherlands in a number of projects usually in conjunction with other techniques as surveys, speed measurements, and accident analyses.

The government has set up a number of subsidized experiments during the past few years such as: the application of experimental measures in 30 km/h zones, school routes and school surroundings and crossing possibilities of busy urban through-roads. Until now these projects have used other techniques such as those mentioned before. At this moment the newly developed DOCTOR technique is applied.
The first impressions of the applications of the Dutch techniques are positive. After a number of applications have been completed a closer look will be taken to see to what extent improvements in the technique can be made. If the conflict observation method is regarded as a method for systematically observing risky behaviour, as part of a road safety theory in which the traffic process is the focal point and not just the accident as a resulting undesirable product, it will be a valuable tool for controlling road safety.

REFERENCES


**DOCTOR OBSERVATION SHEET**

<table>
<thead>
<tr>
<th>Observer</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEATHER:</td>
<td>Municiplity:</td>
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<tr>
<td>ROAD:</td>
<td>OBSERVATION-PERIOD:</td>
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<table>
<thead>
<tr>
<th>DATE:</th>
<th>ROAD:</th>
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<tbody>
<tr>
<td>WEATHER:</td>
<td>dry</td>
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<table>
<thead>
<tr>
<th>SEVERITY OF CONFLICT</th>
<th>TIME CONFLICT</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>slight</td>
<td>severe</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MIN. TTC</th>
<th>PET</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.5s</td>
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<table>
<thead>
<tr>
<th>EXTENT OF CONSEQUENCES</th>
<th>MANOEUVRE AND PARTICIPANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>small</td>
<td>great</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CONFLICTTYPE</th>
<th>MANOEUVRE AND PARTICIPANTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr.1</td>
<td>Nr.2</td>
</tr>
<tr>
<td>car</td>
<td>lorry, bus</td>
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<tr>
<td>bicycle</td>
<td>pedestrian</td>
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</table>

<table>
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<th>SPEED</th>
<th>MANOEUVRE AND PARTICIPANTS</th>
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<tbody>
<tr>
<td>0 - 15 km/hr</td>
<td>A</td>
</tr>
<tr>
<td>15 - 30 km/hr</td>
<td>C</td>
</tr>
<tr>
<td>30 - 50 km/hr</td>
<td>E</td>
</tr>
<tr>
<td>50 - 70 km/hr</td>
<td>G</td>
</tr>
<tr>
<td>70 - 100 km/hr</td>
<td>I</td>
</tr>
<tr>
<td>&gt; 100 km/hr</td>
<td>K</td>
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</table>

<table>
<thead>
<tr>
<th>AVOIDING ACTIONS</th>
<th>MANOEUVRE AND PARTICIPANTS</th>
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<td>no reaction</td>
<td>A</td>
</tr>
<tr>
<td>controlled</td>
<td>C</td>
</tr>
<tr>
<td>uncontrolled</td>
<td>E</td>
</tr>
<tr>
<td>braking</td>
<td>G</td>
</tr>
<tr>
<td>accelerating</td>
<td>I</td>
</tr>
<tr>
<td>swerving</td>
<td>K</td>
</tr>
</tbody>
</table>

**REMARKS:**
Development of traffic conflict techniques in Austria took place in a comparable way it did in Germany: as far as on-the-spot-registrations of traffic-conflicts are concerned, the definition developed and used in Germany was also used in Austria as a basis for the registration of conflicts.

For some special aims we decided, although, to try to use traffic conflict techniques in a modified way referring to data concerning the traffic behavior of individuals. It seemed reasonable to register traffic-conflicts out of an observed subject's car. To get those data it is not enough to watch one individual once at one section of the road network only, as one does observing conflicts on the spot.

What do we want a larger amount of behavioral data of individuals for?

- It seemed interesting to us to analyse the distribution of some special behavioral data, in order to find methodologically based possibilities, to compare individuals to each other.

- Data describing individual behavior in road-traffic were to be compared with the results of indoor-test-data using them as basis for validation-work.

As said above it is not possible to get such behavioral data only by observations-on-the-spot. Therefore we decided, to follow subjects and observe their behavior during a somewhat longer period. There a question arose: Are subjects to be observed with or without their knowledge? It is to expect, that subjects behave more spontaneously if they don't know that they are observed. On the other hand, observation without the knowledge of the subjects leads to some other problems:

- Practically speaking, it is impossible to have a group of persons - and only those persons - driving on the same route without their knowledge.

- If, by chance, all persons, or at least some of them, tested in a laboratory situation would drive on the same route, there is still the question, if they do that for a time which is sufficient, for gathering enough data.
Moreover, one had to do detective work in order to find out, whenever a person, which is to be observed, enters his car, and one would have to do quite a lot of following after, before that person once drives on that special route, thus providing the observer with standardized data.

Former analyses have shown, that observation with the knowledge of the observed subject do change the behavior of the latter only during the first 10 to 15 minutes. After that, so behavioral scientists found out, the typical behavior of the subjects is appearing. It can not be "hidden" for longer than that. That means, that data collected in observations with the knowledge of the subjects can be used for our aims, if we don't register behavioral aspects before 10 to 15 minutes have passed.

Therefore we decided to select an observation route and to observe the subjects in question behavior on that specific route:

- The observation route was selected in Vienna; a large number of subjects who had been tested at the Austrian Road Safety Board (~400) were observed on that route.
- The standardized route consists of a first section of approximately 15 minutes, where no data are registered, followed by 50 minutes where the subject has to drive along typical roads of Eastern Austria and is observed.

Doing observations with the knowledge of the subjects, one can decide to observe out of the subject's car or to follow after the subject in another car. Pre-tests showed, that the movements of vehicles can be observed better out of a following car, but the behavior of the observed person itself can only be observed in a reasonable way when sitting in the subject's car.

- Therefore we decided to do behavioral observations out of the observed subject's car.

As an important step we had to decide on those variables which had to be considered by the observers. Discussions of experts lead to the following decisions.

- Registration of critical resp. eye-catching events should be accompanied by a standardized and continual description
of the driver's behavior according to well-defined behavioral variables.

Following that kind of reasoning two observers were to collect the data: one of them should register eye-catching events (we called him "free observer"), the second one should describe the subject's behavior, using a coding scheme (we called him for coding-observer).

- The critical events the free-observer had to register should be
  - communication processes with other traffic participants,
  - erroneous behavior,
  - and traffic conflicts.

- The coding observer had to use a scheme containing 23 behavioral variables which - following pre-tests and discussions - should be sufficient to describe the subject's behavior in a continual and standardized way.

The definition of traffic conflicts for the observation out of the moving car is the same as for on-the-spotRegistrations:

A traffic conflict is an observable event which would end up in an accident unless one of the involved parties slows down, changes his direction, or accelerates to avoid a collision. The later one of the parties involved reacts correspondingly, the higher the danger of a collision. For the training of observers, we started with video recordings of car rides on the observation route, followed by observations in the field together with the trainer, collecting data of at least 25 subjects driving their car along the test-route.

There is one important aspect concerning the criteria for the decision, if one just has observed a conflict or not, which is not available when observing on the spot:

The driver can also feel sudden breaking manoeuvres, changes of direction or accelerations. That, in our eye is in a way raising into rate-correlation and reliability.
Introduction

In the Research Unit for Traffic Engineering and Infrastructure Planning at the Katholieke Universiteit Leuven, Belgium, research was done to find

a) low budget solutions for traffic data collection and analysis;

b) methods for preparing better programmes to enhance traffic safety for the different categories of road users.

To increase the efficiency of data collection and analysis, the research unit designed a system linking a video recorder with a microcomputer (ref. 1, 2). This system has recently been used for flow counts at the intersections where traffic conflicts were observed.

1. Data collection and analysis of traffic conflicts

As a part of an assignment by the Ministry of Public Works and the Ministry of Transport to make a traffic conflict technique operational in Belgium, the Research Unit carried out a traffic conflict analysis at 8 intersections, all situated in the neighbourhood of the city of Leuven (ref. 3, 4, 5 and 6).

The starting point of this study was the formal definition of a traffic conflict, which was agreed upon at the first workshop on traffic conflicts (Oslo, 1977): "A traffic conflict is an observable situation in which 2 or more road users approach each other in time and space to such
an extent that a collision is imminent if their movements remain unchanged.
However, observers were instructed not only to record such conflict situations, but also any special, remarkable traffic situation which could produce interesting information about local road user behaviour. 5 conflict severity grades were considered: light conflict, medium conflict, serious conflict, minor collision and major collision. Each conflict was recorded on a separate recording sheet. When the observation sessions at an intersection were finished, all conflict information was coded and used as input data for a microcomputer. A processing program was developed to produce a clearly-structured output for traffic safety analysis.

Pieces of such a computer output for a certain intersection is found in tables 1 to 6. Figure 1 shows the plan of the intersection.

Figure 1.
Table 1 is the first page of the computer output: it contains some general information about the intersection, the observation periods, the number of conflicts per severity grade and a conflict distribution over the day. Very interesting information about the most conflicting non-pedestrian manoeuvres at the intersection is to be found in table 2. The upper part of this table is the conflict flow table for all conflict grades: e.g.: 19 times a conflict was observed between a vehicle driving from leg 1 of the intersection to leg 4 and a vehicle coming from leg 4 and driving to leg 2. A similar conflict flow table in the lower part of table 2 is for all conflict grades except the light ones. The representation of pedestrian conflict flows is somewhat different.

For 3 categories of road users (motorists, cyclists and pedestrians), a conflict table can be drafted. Table 3 shows the motorists conflict table during the 23 hours observation period. It appears that 17 times a motorist approaching the intersection via leg 4 and leaving via leg 2, was involved in a conflict.

In order to obtain the information of table 4, vehicle flow counts of the different intersection manoeuvres were carried out during selected periods of the observation periods (4 thirty minutes periods). The number of vehicles for the selected periods were extrapolated to the 23 hours observation periods. For the flow counts, video recordings of the intersection were used together with a microcomputer.

The combination of tables 3 and 4 results in a risk table, as shown in table 5. Each element of the matrix is calculated as the ratio of the number of conflicts to the number of vehicles (the symbol '/' indicates an indefiniteness: no vehicle flow, no conflict observed). A risk factor for the whole intersection can also be evaluated.

To verify the precision of the limited flow counts at the intersection, a second risk table (table 6) was calculated, based on flow counts by the Ministry of Public Works a few months earlier. The comparison of the 2 risk tables illustrates that the results in table 5 are quite accurate, providing that the selection of the flow count periods is done in a sensible way.

This is only a selection of the computer output, based on the traffic conflicts and flow counts. The interpretation of these results is reserved to experts in the field of traffic safety.
TRAFFIC CONFLICTS OBSERVATIONS: RESULTS

*** GENERAL INTERSECTION INFORMATION:
* LOCATION: KESSEL-LO
* INTERSECTION LEGS:
  1. DIESTSESTWG-DIEST
  2. LEUVENSESTRAAT
  3. IJZERENWEGSTRAAT
  4. DIESTSESTWG-LEUVEN
* ASPHALT ROAD SURFACE
* CONTROLLED BY TRAFFIC SIGNALS

*** NUMBER OF OBSERVATION HOURS: 23

<table>
<thead>
<tr>
<th>OBSERVATION PERIODS</th>
<th>011085</th>
<th>031085</th>
<th>071085</th>
</tr>
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<tbody>
<tr>
<td>7 - 8 - 9 - 10 - 11 - 12 - 13 - 14 - 15 - 16 - 17 - 18</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
</tr>
</tbody>
</table>

*** NUMBER OF CONFLICTS: 48

- LIGHT CONFLICT: 33 (68.7%)
- MEDIUM CONFLICT: 12 (25%)
- SERIOUS CONFLICT: 3 (6.2%)
- MINOR COLLISION: 0 (0%)
- MAJOR COLLISION: 0 (0%)

* NUMBER OF CONFLICTS PER OBSERVATION HOUR: 2.1
* NUMBER OF NON-LIGHT CONFLICTS PER OBSERVATION HOUR: 0.65

*** CONFLICT DISTRIBUTION OVER THE DAY

<table>
<thead>
<tr>
<th>OBSERVATION PERIOD</th>
<th>011085</th>
<th>031085</th>
<th>071085</th>
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<td>- - 0 1 1 2 2 0 1 2</td>
<td>- - 0 3 3 1 1 3 3 0</td>
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<td>- - 1 0 0 0 0 0 - - - -</td>
<td>0 0 0 0 1 1 3 2 - -</td>
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</tbody>
</table>

Table 1
### NON-PEDESTRIAN CONFLICTS PER CONFLICTING TRAFFIC FLOWS

**LEG 1**: DIESTSESTWG-DIEST  
**LEG 2**: LEUVENSESTRAAT  
**LEG 3**: IJZERENWEGSTRAAT  
**LEG 4**: DIESTSESTWG-LEUVEN

* **NUMBER OF NON-PEDESTRIAN CONFLICTS**: 35

#### CONFLICT FLOW TABLE

(13 = NON-PEDESTRIAN ROAD USER FROM LEG 1 TO LEG 3)

<table>
<thead>
<tr>
<th></th>
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<th>13</th>
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<th>21</th>
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* **NUMBER OF NON-LIGHT NON-PEDESTRIAN CONFLICTS**: 12

#### CONFLICT FLOW TABLE

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</table>

Table 2
** MOTORISTS CONFLICT TABLE (23 hours):**

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<th>3</th>
<th>4</th>
<th>total</th>
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Table 3.

** MOTORISTS FLOW TABLE (23 hours): - extrapolated -**

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<th>4</th>
<th>total</th>
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<td>38715</td>
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</table>

Table 4.
** MOTORISTS RISK TABLE (based on the extrapolated flow table) **

(all table values must be multiplied by 10 )

<table>
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<td>/</td>
<td>/</td>
<td>/</td>
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<td>0</td>
<td>2.7</td>
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<td>/</td>
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</tbody>
</table>

* risk factor intersection: 1.55

Table 5.

** MOTORISTS RISK TABLE (based on flow counts by the Ministry of Public Works) **

(all table values must be multiplied by 10 )

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
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<td>3.8</td>
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<td>2.3</td>
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<td>3.9</td>
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<td>/</td>
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</tbody>
</table>

* risk factor intersection: 1.66

Table 6.
2. The use of risk rates for an appropriate interpretation of safety programmes

The rehabilitation of road infrastructure for safety reasons needs a large amount of money. To use financial resources more judiciously traffic managers should have information on the risks that road users can run while performing different manoeuvres. Therefore risk rates of different manoeuvres at different intersections should be calculated.

The probability that a person using intersection \( k \) is performing manoeuvre \( i \rightarrow j \) can be written:

\[
MP_k(i \rightarrow j) = \frac{M_k(i \rightarrow j)}{\sum_{i=1}^{n} \sum_{j=1}^{n} M_k(i \rightarrow j)}
\]

with

- \( MP \) : manoeuvre probability
- \( M_k(i \rightarrow j) \) : number of persons performing manoeuvre \( i \rightarrow j \) at intersection \( k \)
- \( n \) : number of intersection legs at intersection \( k \)

The probability that a person performing manoeuvre \( i \rightarrow j \) at intersection \( k \) is involved in a conflict can be written:

\[
CP_k(i \rightarrow j) = \frac{C_k(i \rightarrow j)}{M_k(i \rightarrow j)}
\]

with

- \( CP \) : conflict probability
- \( C_k(i \rightarrow j) \) : number of conflicts while performing manoeuvre \( i \rightarrow j \) at intersection \( k \)
- \( M_k(i \rightarrow j) \) : number of persons performing manoeuvre \( i \rightarrow j \) at intersection \( k \)

The risk that a person using intersection \( k \) is involved in a conflict while performing manoeuvre \( i \rightarrow j \) can be calculated as follows (combined probability):

\[
R_k(i \rightarrow j) = MP_k(i \rightarrow j) \cdot CP_k(i \rightarrow j)
\]
When \( m \) intersections are concerned in a safety study the maximum risks that a person can run at these intersections determine the required safety programme. For that purpose it is necessary to know the maximum values of:

\[
R_k(i\rightarrow j) = \frac{M_k(i\rightarrow j)}{n \sum_{i=1}^{n} \sum_{j=1}^{n} M_k(i\rightarrow j)}
\]

\[
C_k(i\rightarrow j) = \frac{C_k(i\rightarrow j)}{n \sum_{i=1}^{n} \sum_{j=1}^{n} M_k(i\rightarrow j)}
\]

To evaluate safety of the different manoeuvres at \( m \) intersections a range of risk rates is helpful, e.g.

\[
R_2(4\rightarrow 2) > R_1(3\rightarrow 4) > R_3(2\rightarrow 1) > R_2(1\rightarrow 3)
\]

From this range can be concluded: the risk that a person is involved in a conflict is higher at intersection 2 performing the manoeuvre 4 \( \rightarrow \) 2 than at intersection 1 performing the manoeuvre 3 \( \rightarrow \) 4 etc.

It is necessary to have risk rates separately for
- motorists
- cyclists
- pedestrians
to develop justified safety programmes for the different categories of road users.

It is also useful for policy making to have risk rates for the traffic during:
- morning peak hour
- evening peak hour
- off-peak hours.

For a given city or region where the rehabilitation of different intersections is necessary the following information about the risk rates (table 7) should be available to traffic managers.
<table>
<thead>
<tr>
<th></th>
<th>Morning peak hour</th>
<th>Evening peak hour</th>
<th>Off-peak hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian</td>
<td>RR(_{MP})</td>
<td>RR(_{EP})</td>
<td>RR(_{OP})</td>
</tr>
<tr>
<td>Cyclist</td>
<td>RR(_{MC})</td>
<td>RR(_{EC})</td>
<td>RR(_{OC})</td>
</tr>
<tr>
<td>Motorist</td>
<td>RR(_{MM})</td>
<td>RR(_{EM})</td>
<td>RR(_{OM})</td>
</tr>
</tbody>
</table>

Table 7.

In this table RR\(_{MP}\) e.g. is the Risk Range during the Morning peak hour for Pedestrians.

Conclusions

Risk analysis needs a large amount of information. For the collection of traffic conflict data the use of human observers in situ is essential. Information about the flow of the different manoeuvres however can be obtained with less manpower using videorecordings. The linking of a video recorder with a microcomputer allows to gather this information on a semi-automatic basis. The computer processing of conflict data and flow information must have an output which leads to an appropriate interpretation of safety programmes by experts in the field of traffic conflict techniques.

Acknowledgements

The author wishes to thank Ir. L. VENSTERMANS for his assistance in conducting the data collection and processing. This paper could also not have been written without the cooperation of the observers in situ. Their help is greatly appreciated.
References


THE TRAFFIC CONFLICTS TECHNIQUE TRAINING PACKAGE.

Mrs. J. S. Swain

Janet
Research Assistant
Accident Research Unit,
Department of Psychology,
University of Nottingham,
University Park,
Nottingham NG7 2RD
England.

Introduction

Local Authorities in the United Kingdom have a statutory duty to carry out a programme of measures designed to promote road safety, including undertaking studies into accidents. However the use of accident data alone to determine the reasons for problems occurring at particular locations has often been found inadequate. Accidents are actually rare events making it necessary to wait several years before there are sufficient incidents for analysis, even then the accident records often contain insufficient and unreliable data.

Considerable research has been undertaken in the United Kingdom to devise a technique capable of detecting, observing, studying and evaluating potential accident locations without necessarily waiting for an accident history to develop. As a result of this research only one technique has so far been found capable of fulfilling all of these aims, and that is the study of potential accidents or "CONFLICTS".

In an effort to promote the use of the traffic conflicts technique within Local Authorities the Transport and Road Research Laboratory funded the development of a Training Package designed to provide an efficient method of training personnel to carry out conflict observations accurately and reliably.

This paper summarises the development of the traffic conflicts technique and then describes in more detail the development and contents of the Traffic Conflicts Technique Training Package.

Development of the Traffic Conflicts Technique

The term "traffic conflicts" introduced by Perkins and Harris (1967), was used to describe potential accident situations which they identified as being useful in the prediction of accidents. They also devised a method of recording conflicts based on the observation of some type of evasive action, such as braking or change of course, taken by a driver in order to avoid a potential collision. This recording method was then developed by Spicer (1971) for use in the United Kingdom. Conflicts between vehicles were found to vary in their severity, and it was decided that they could be classified into one of five grades according to the severity or suddenness of the evasive action taken and the proximity of the vehicles involved. A description of the five grades is given in Table 1. Following further research by Spicer it was decided in 1977 that a new Grade 2+ was necessary.
TABLE 1. Conflict Severity Grade Classification

<table>
<thead>
<tr>
<th>CONFLICT GRADE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1 1</td>
<td>Precautionary braking or lane change or other</td>
</tr>
<tr>
<td></td>
<td>anticipatory braking or lane change when risk of</td>
</tr>
<tr>
<td></td>
<td>collision minimal.</td>
</tr>
<tr>
<td>2 2 1</td>
<td>Controlled braking or lane change to avoid collision but with ample time for manoeuvre.</td>
</tr>
<tr>
<td>- 2+ 2</td>
<td>Braking or lane change to avoid collision with less time for manoeuvre than for a slight conflict or requiring complex or more severe action.</td>
</tr>
<tr>
<td>3 3 3</td>
<td>Rapid deceleration, lane change or stopping to avoid collision resulting in a near miss situation (no time for steady controlled manoeuvre).</td>
</tr>
<tr>
<td>4 4 4</td>
<td>Emergency braking or violent swerve to avoid collision resulting in a very near miss situation or minor collision.</td>
</tr>
<tr>
<td>5 5 5</td>
<td>Emergency action followed by collision.</td>
</tr>
</tbody>
</table>

Grade 1 conflicts were no longer recorded as they failed to satisfy this definition, and the other grades were re-scaled. The effect of the 1977 and 1979 revisions are also shown in Table 1.

In an attempt to maximise the reliability of the classification of conflicts experienced observers were asked to describe the factors they took into consideration when judging the severity of an incident. Four factors emerged, each with up to five levels of severity, as shown in Table 2 below.
FACTOR

A. Time before the possible collision that the evasive action commenced.

B. Severity or rapidity of the evasive action.

C. Complexity of the evasive action.

D. Proximity of the vehicles involved when the evasive action is terminated.

SEVERITY LEVELS

LONG, MODERATE, SHORT

LIGHT, MEDIUM, HEAVY, EMERGENCY

SIMPLE, COMPLEX

GREATER THAN 2 CAR LENGTHS,
1 - 2 CAR LENGTHS,
1 CAR LENGTH OR LESS,
MINOR COLLISION,
MAJOR COLLISION

TABLE 2. FOUR FACTOR LEVELS

Observers were then required to assess a conflict along all four factors by recording the level of each factor which best described the incident. A final severity grade for the conflict can then be obtained by referring to Table 3, which defines the relationship between the different combinations of the various levels of the four factors and the five conflict grades. This four factor method was compared with original grading technique by Lightburn and Howarth (1980). They found greater consistency between observers in the recording and classification of conflicts using the four factor method.

The Traffic Conflicts Technique Training Package

The original idea for a Training Package came from Mr. S. J. Older formerly of the Transport and Road Research Laboratory, but the research and development of the package was conducted by the Accident Research Unit, Nottingham University under contract to the Transport and Road Research Laboratory.

Development of the Package

A survey of local authorities in England and Wales was conducted to determine the extent to which conflict studies were already being used and the type of personnel carrying out the observations. Fifty-three percent of these authorities said they already used conflict studies when investigating accident causation, employing traffic engineers as observers, making the studies expensive to conduct. It was felt that more authorities would use conflict studies if they could be conducted at a lower cost by employing casual personnel as observers. Lightburn and Howarth (1980) had established that it was possible to train persons with no previous experience in this field to carry out reliable conflict observations. Therefore the aim of the Package was to provide local authorities with a comprehensive guide for the training of casual personnel to carry out conflict observations accurately and reliably. Of the authorities surveyed 65% said a Training Package would be useful to them. Opinions concerning
<table>
<thead>
<tr>
<th>PROXIMITY</th>
<th>TIME</th>
<th>LONG</th>
<th>MODERATE</th>
<th>SHORT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SEVERITY</td>
<td>LIGHT</td>
<td>MEDIUM</td>
<td>LIGHT</td>
</tr>
<tr>
<td></td>
<td>TYPE</td>
<td>SIMPLE/</td>
<td>SIMPLE/</td>
<td>SIMPLE/</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COMPLEX</td>
<td>COMPLEX</td>
<td>COMPLEX</td>
</tr>
<tr>
<td>&gt; 2 Car Lengths</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 - 2 Car Lengths</td>
<td></td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1 Car Length</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>or less</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor Collision</td>
<td></td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Major Collision</td>
<td></td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3. Conversion of Factor Levels to Conflict Grades.
the format and contents of the proposed package were obtained from those authorities having experience with conflict studies and these were taken into consideration during its production.

**Original Training Package**

A package was produced by the Accident Research Unit consisting of a Training Manual and a 16 mm time-lapse film containing examples of real-life conflicts. The Manual contained information on the rationale, design and execution of a conflict study, together with details of how to train potential observers using the four factor classification technique. However only four grades of conflict severity were defined because the two levels, Minor Collision and Major Collision, of the fourth factor Proximity were removed thus eliminating Severity Grade 5.

An Introductory Training Manual was included which explained to the trainees the concept and formal definition of a conflict and how they should be recorded and classified. Also contained in this booklet were exercises associated with the filmed examples to be completed by the trainees in the Answer Booklet provided. The responses to the exercises were then used to assess the trainees performance. Finally the Manual suggested that the trainees be given additional instruction and assessment in a real life situation.

**Evaluation of the Training Package**

A contract was then awarded to the Accident Research Unit, Nottingham University, to evaluate the usefulness of the Training Package to local authorities in the design and execution of conflict studies. A major part of this evaluation was to discover whether or not the Package enabled authorities to train casual observers to detect and classify conflicts accurately and reliably.

Each of the participating local authorities trained their observers using the Package and then conducted conflict observations at locations of their choice. An "expert" observer from the Accident Research Unit recorded conflicts alongside the local authority observers. This "expert" thus acted as a standard with which to compare the various observers. Data obtained were analysed to determine the inter-observer reliability achieved. Instructors' and trainees' reactions to the Package, the problems they encountered and the areas they felt needed improving were also examined.

All the authorities concerned seemed to be impressed with the Traffic Conflicts Technique and on the whole the Training Package was very well received. Generally the comments and criticisms made were consistent across authorities and suggested that various amendments to the Package were necessary if it was to be used effectively. It became apparent that more detailed instruction was required regarding the detection, recording and classification of conflicts as problems in these areas were encountered by certain trainees. For example, some trainees were applying their own definition of a conflict and as a result dismissing certain incidents as part of "normal" driving.
Criticisms relating to the actual method of training tended to focus on the time-lapse film and associated exercises. Both instructors and trainees disliked the jerky two-frame per second presentation of the film. They expressed a preference for video to enable a smooth presentation with sound. Amendments to the contents of the film were also recommended. The examples of conflicts were too limited and the question of detection was omitted altogether.

Results of this evaluation suggested that the observers' performances could have been improved by more thorough training. Although the instructors adhered to the recommendations given in the Manual relating to the initial training of observers, they seemed to disregard the suggestions for assessment and possible retraining. They also tended not to follow many of the recommendations made concerning the design and execution of a Traffic Conflicts Study. These findings indicated that it was necessary to include in the Manual guidelines on the length of indoor training required, and the form that any re-training should take, together with an emphasis on the need for detailed training and practise in the field, plus adequate pre-study investigations by the supervisor. Instructors/supervisors need to be made aware that it is essential to give precise and detailed instructions to observers regarding the information they should record in addition to the four factors, the position they should observe from etc.

On the basis of this evaluation study a revised version of the Traffic Conflicts Technique Training Package was produced.

REVISED TRAFFIC CONFLICTS TECHNIQUE TRAINING PACKAGE

The format of this Package is basically the same as the original in that it consists of a Training Manual for the instructor, Training Video, Trainees' Handbook and Answer Booklet. All the information required to enable an instructor to design and execute a conflict study as well as train personnel to carry out conflict observations is contained in the Training Manual. The Trainees' Handbook aims to be self-explanatory and covers all the essential aspects of the traffic conflicts recording technique. At various stages in the training real-time video-taped incidents are presented which the trainees are required to assess in the Answer Booklet.

TRAINING MANUAL

The following information and recommendations are presented to the instructor in this section of the Package.

(i) Introduction to Traffic Conflict Studies: The instructor is presented with the formal definition (Oslo 1977) of a conflict which is then expanded upon, together with a brief discussion of the advantages, limitations and potential uses of Traffic Conflict Studies.

(ii) Designing a Conflict Study: The importance of this stage is emphasized since it is a crucial aspect in the success of a conflict study. Detailed information concerning the procedures which should be followed are provided. Guidelines on the factors to be considered when making decisions regarding the selection of sites for study, the timing and duration of the observations and the number of observers required are also included.
<table>
<thead>
<tr>
<th>DAY</th>
<th>SUMMARY OF TRAINING</th>
</tr>
</thead>
</table>
| A.M. | First half of the Trainees' Handbook  
      | i.e., Introduction to the Traffic Conflicts  
      | Technique.  
      | Definition of a Conflict.  
      | Situations in which conflicts can occur.  
      | Factors A - D, video examples and  
      | associated exercises.  
      | Discussion of exercises and any problems  
      | arising. |
| P.M. | Second half of the Trainees' Handbook  
      | i.e., Conversion of Factor Levels to Conflict  
      | Grade.  
      | Recording sheets, video examples and  
      | associated exercises.  
      | Detection exercise.  
      | Other video examples of different Grades  
      | of conflicts.  
      | Discussion of Training so far, problems  
      | arising from the exercises and any  
      | questions trainees have.  
      | Summary.  
      | Introduction to on-site trial observations. |
| A.M. | Practise detecting and recording conflicts at  
      | a site of similar layout to the one used in the  
      | video. |
| P.M. | Group discussion of problems encountered and any  
      | questions arising from these observations. |
| A.M. | Visit a study site of similar layout to the one  
      | in the video and practise recording conflicts  
      | for half to one hour.  
      | First stage of the Reliability Study, where  
      | trainees spend 2 hours recording and classifying  
      | conflicts identified for them by the instructor/expert. |
| P.M. | Second stage of the Reliability Study, where  
      | trainees spend 2 hours recording and classifying  
      | conflicts they detect occurring.  
      | Instructor to analyse the data from the Reliability  
      | Study and arrange any re-training necessary. |

**TABLE 4. Suggested Training Programme**
(iii) Training Observers: Before attempting to train the observers the prospective instructors must train themselves thoroughly so that they can be considered experts against whom the observers can be compared. The Trainees' Handbook is designed to be self-explanatory, therefore instructors should be able to use it to train themselves.

Since the aim of the Training Package is to provide a method of training casual personnel to detect and classify conflicts accurately and reliably, it is necessary to ensure that the observers are using the same criteria to

a) Detect a Conflict
b) Classify a Conflict

Broadly, the training is divided into two parts - Trainees Handbook with Video and On-Site Trial Observations. A suggested Training Programme (reproduced in Table 4) giving a brief outline of the training and time scale involved is included. Although the Trainees' Handbook is largely self-explanatory it is suggested that after allowing the trainees to read through a section the instructor reviews its contents to ensure complete understanding. This also gives the trainees an opportunity to ask questions. Full instructions on the presentation of the Training Video are also given, together with the answers to the associated exercises and a brief discussion of the assessment of a trainee's performance.

Having completed the training detailed in the Handbook it is then suggested that the trainees be given additional on-site instruction. The value of such training is emphasized and it is made clear that the information presented in the Handbook, video-taped examples of conflicts and associated exercises provide an Introduction only to the detection and recording of traffic conflicts. A detailed description of how to conduct on-site trial observations is provided in this section of the Manual. Once the trainees have had some time to practise detecting and recording conflicts on-site, it is necessary to conduct a reliability study to ensure that all the trainees and the "expert" (instructor) are detecting the same incidents as conflicts, and then classifying them in the same way. Information on how to analyse the data obtained from such a reliability study is also provided.

(iv) Executing a Conflict Study: Decisions concerning exactly where and how the study will be conducted should already have been made during the Design stage. At this point it is stressed that the observers should be given very precise and explicit instructions to ensure that they carry out observations that will be useful in the study. Information on how to analyse the conflict data collected is provided. Once the analysis is complete the local authority should be in a position to decide upon the remedial measures necessary, if any, and then a further conflict study could be used to evaluate the effectiveness of the measures implemented.

TRAINEES' HANDBOOK

The following information is presented to the trainees in this handbook.

(1) Introduction to the Traffic Conflicts Technique: The concept of a traffic conflict is introduced followed by the formal definition. This definition is then analysed and the criteria that dictate whether or not any
(ii) Detection, Classification and Recording of Conflicts: This section of the Handbook centres around the training video which contains both contrived and real-life examples of conflicts. The Four Factor Conflict Recording Technique is introduced, the four factors being described as per Table 2. Each factor is then explained in detail, and video examples of incidents illustrating the various severity levels of the different factors are presented. The Handbook also describes how to calculate the final severity grade of a conflict from the four factors, and how to enter a complete conflict on the recording sheet provided, (illustrated in Figure 1). At the end of each stage of training the trainee is required to complete certain exercises associated with incidents on the video. The purpose of these exercises is to provide the instructor with a means of assessing whether or not the trainees are ready to progress with the training, and if they are not, then it should be obvious which aspect they are experiencing problems with.

(iii) Summary: The training contained in the Handbook is very briefly summarised and again described as an introduction to the detection and recording of traffic conflicts. The value and importance of the on-site training and practice which is to follow is also discussed. At all stages the trainees are given every opportunity to ask questions and every effort is made to enable the instructor to ascertain whether or not they have fully understood the information presented.

This revised Training Package has been presented to the Local Authorities who participated in the evaluation of the original. They have said that they feel the problems of the original have been overcome in this version and that the video is an improvement over the 16 mm time lapse film. The Transport and Road Research Laboratory are at present considering where and in what form the Package should be published.

REFERENCES


PROCEEDINGS FIRST WORKSHOP ON TRAFFIC CONFLICTS (1977) Institute of Transport Economics, Oslo.


**VEHICLE 1.** is the one whose actions cause the conflict.

**VEHICLE 2.** is the one that has to take the avoiding action.

**FIGURE 1.** Conflict Recording Sheet
1. INTRODUCTION

The traditional method of determining traffic safety is based on statistics of traffic accidents. But it often does not correspond to the requirements of traffic engineering and research. Traffic accidents are statistically relatively rare events. That is why we can consider as valid only 4-5 years accident statistics. For example, changed traffic regulations give obvious results after years. At the same time we must take into account that only a part of all accidents could be registered by officials. Therefore, it is suitable to use different events on determining traffic safety, such we can call as risk situations in general. These situations must be easily recorded and statistically more frequent events than accident.

First study in the USSR using the Traffic Conflicts Technique (TCT) was carried out by Road and Traffic Research Laboratory of Tallinn Technical University in 1979. There was used original criteria of traffic conflicts developed in USA (Perkins, Harris 1968). As the results were encouraging we decided to start a new series of investigations in 1982. Compared to above mentioned we decided to make some modifications in method we used. It was decided to determine the conception of potential conflict. In 1983 we started to use videorecording on investigations. But the objective instants were not contained in conflict criteria, that
was based on subjective appointments of investigators.

The TCT got more popularity and that caused a subsequent supplementing of the method. Investigations made after 1984 use time-to-collision as criteria of the conflict, and demand that there must be a collision course between the participants.

The basic idea and result of investigations was the elaboration of instructions of the technique and detection of the conflict-accident connections. In last years we have carried out some ordered studies in traffic engineering area using the TCT operational tool.

There is a mathematical simulation model in control stage. We have set up a goal to make it usable for evaluating traffic safety and intersection traffic conditions in design stage.

Side by side with Tallinn Technical University, Moscow, Vilnius, Kiev and other centers are engaged in the TCT problems.

2. DEFINITIONS.

The conflict technique used at present defines a conflict as a situation in traffic, where at most t seconds before a potential collision one of drivers brakes or weaves to avoid collision. t - we call time-to-collision value. The quantity of t depends on speed limit, types of vehicles participated in conflict and some other local conditions.

Conflicts are grouped into 3 categories on an urgency scale: - slight (or potential) conflicts - precautionary braking or lane change, when risk of collision minimal.
- moderate conflicts. There is no time for steady controlled manoeuvre, deceleration is rapid.
- serious conflicts. Emergency braking or violent swerve to avoid collision resulting in a very near miss situations.

Therefore the obligatory elements of the conflict definitions area are:
- at least one of the participants must be a vehicle
- there must exist a collision course
- at least one of the participants must take evasive action (braking or weaving to avoid collision)
-evasive action must be taken at most \( t \) seconds before potential collision (time-to-collision value). Usually \( t \)-value is 1...2 seconds.

There are distinguished 6 classes of conflicts, grouped in 16 types:
- rear-end conflicts (types 1...5)
- head-on conflicts (type 6)
- lane-change conflicts (types 7...8)
- cross-traffic conflicts (types 9...14)
- pedestrian conflicts (type 15)
- others (type 16)

3.FIELD STUDIES.

The basic contingent of investigators have been durable and acquired sufficient experience and requisite accordance. The training of new investigators is made in three stages:
- A-theoretical part. Introduction in the principles of the technique.
- B-laboratory part. Investigations from video-recorder in laboratory conditions with further analysis.
- C-field part. Conflict countings in field conditions, further analysis and control.

Investigators must have basic knowledge in traffic engineering. The control tests have shown that coincidence in case of investigators of basic group is more than 90%, and 85%-preparation group. Traditionally the investigation group consists of 2 investigation vehicles with 4 investigators on an intersection. The investigation vehicles are placed on a major street about 50 m from intersection. Two of investigators are counting conflicts, and two-traffic stream. As far as possible the investigation vehicles must be placed on parking grounds, yards etc. causing minimal attention. We can't use special purpose vehicles (like police) of course. Often the video-recording makes demands to the dwelling-place of the investigation vehicle.

Investigations in 1981-85 were carried out on urban non-signalized intersections with speed-limit 60 kmph. Further
investigations include both signalized intersections and outside of intersection space. We have often used video-recordrs, digital timers, speed meters and other devices. The special equipment developed for traffic countings could be useful.

Registering field conflict countings we use special forms with columns for types of conflict, time, participants and other information we need. Traffic stream data will also be registered.

Conflict countings are usually carried out on Tuesdays, Thursdays or Wednesdays: on two days both during 7 hours—in all, 14 hour of investigation. On urban intersections the counting period lies usually between 8-11.30 p.m. and 2-5.30 a.m. The countings are carried out in April, May, June, September or October. Special investigations could be realized during different periods.

4. ANALYSIS AND RESULTS.

The analysis of collected data based on filled forms and supplementary overhaul of videotapes. The basic aim of investigations was to compare the validity of conflict data and accident data. 5 years accident history registered by police was used. We have computed correlation coefficients between annual accident data and average conflict data by classes. The results of the correlation analysis have shown that conflicts are statistically significantly related to accidents. It was possible to evaluate the length and accuracy of investigation by using accommodated data. We have fixed that investigation period must be at least 10 hours (on traffic stream 400...1500 vph). Most suitable periods for investigation were determined. As the results were significant in comparison with traditional methods, it became possible to use the TCT as operational tool. In 1985/86 we have investigated the efficiency of road marking on coordinated main streets in Tallinn by using the Traffic Conflicts Technique.
6. FUTURE ACTIVITIES.

Future investigations are planned in following directions:
- specifying a conflict criteria by using objective data
- introducing semi-automatic countings
- determining the local influence to counting data
- operational investigations on critical points
- observing international development of the TCT.
IV. TRAFFIC CONFLICT TECHNIQUE APPLIED IN RESEARCH AND FOR PRACTICAL APPLICATION

Gledec, Mladen  Application of traffic conflict technique and driver performance measures in analysis of hazardous crossroads

Draskóczy, Magda  First experiences with the application of traffic conflicts technique

Kulmala, Risto  The effects of a varying speed limit at a highway junction

Brown, Gerald  Application of traffic conflicts for intersection hazards and improvements

Tykesson, Stefan  The usage of traffic conflict technique on the Swedish national road network

Risser, Ralf  Application of traffic conflict techniques in Austria
1. Introduction

Preparing by the realisation of first Road Safety Programme in SR Croatia certain number of dangerous crossroads in Zagreb have been analysed with the aim of giving proposals for improvements and solving of road safety problems. Beside accident analysis traffic conflict techniques and driver performance measures have been used as the analytic tools. Procedure applied and results achieved in that procedure, from one of those crossroads in Zagreb are presented in further.

2. Basic characteristics of the crossroad

Scheme and basic characteristics of treated crossroad are presented in figure 1. As it is seen from that figure this crossroad is with four legs, almost at right angle each other. Control of traffic flows is by traffic lights, except on section X-X (figure 1), where there is neither zebra-crossing for pedestrians, neither traffic light.

Horizontal signalisation on crossroad is in bad conditions. Pavement's surface is rather good, except ruts that are present on major road. There is public lighting with weak illumination.
FIGURE 1 GENERAL VIEW OF THE CROSSROAD
Eastern leg of major road is in curve with the centre of curvature on northern side. Inside of that curve there are high bushes that hinder the clearness along the road.

3. Traffic accident analysis

Three years period; (1983-1985) has been comprehended in that analysis. Pattern of accidents according to the type from mentioned period is presented in table 1.

Table 1 Type of accidents in period 1983-1985

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Head on</td>
<td>18</td>
<td></td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Rear end</td>
<td>24</td>
<td>29</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Side on</td>
<td>18</td>
<td>29</td>
<td>26</td>
<td>24</td>
</tr>
<tr>
<td>Left turning</td>
<td>29</td>
<td>35</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>11</td>
<td>7</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>-</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Distribution of accidents in year 1983 is presented in collision diagram in figure 2.

Analysis of the accidents resulted as follows:
- The most frequent type of accident is with left turning, in 28% at average.
- The most frequently accidents are happening between hours 18:00 and 24:00, in 43% at average.
SPEED LIMITS
A - 60 Km/h
B - 60 Km/h

15 ACCIDENTS
1 KILLED
4 INJURED

(A) MAJOR ROAD

(B) MINOR ROAD

SPEED LIMITS:
A - 60 Km/h
B - 60 Km/h

NOTE:
- MOVING VEHICLE
- BACKING VEHICLE
- PEDESTRIAN
- PARKED VEHICLE
- FIXED OBJECT
- REAR END
- HEAD ON
- SIDE SWIPE
- OUT OF CONTROL
- LEFT TURN
- RIGHT ANGLE

LOCATION:

COMMENTS:
- Nearly every second accident is happening at night, in 49% at average.
- About 75% of all accidents are happening in dry pavement conditions.
- The most frequent cause of accidents (in 47% of all cases) is violation of giving way.

4. Drivers' behaviour on crossroad

It has been estimated that one of the most important characteristics of drivers' behaviour was speed of movements; especially on the major road, in direction east-west. Speeds of vehicle in that direction have been measured systematically; in free traffic flow and in the leading of the motorcade. Histogram of speeds' frequencies is presented in figure 3.

Speeds of vehicle are in area between 45 and 85 km/h.

Speed limit, as it is seen in figure 2, is 60 km/h. That speed of limit is respected by the 70% of vehicles.

Almost every third driver drives at speed higher than posted speed limit is.

However, it is necessary to mention that this crossroad is one in series on the major road with synchronised traffic lights at advanced speed of 60 km/h.

5. Traffic conflicts analysis

Conflict technique developed by Lund Institute of Technology has been used for data collecting of traffic conflicts on the crossroad. Total registering time has been 3 hours and 15 minutes. It was regarded narrowly sufficient time period.
FIGURE 3  SPEEDS IN MAJOR ROAD - DIRECTION "EAST - WEST"

V₅₀ = 58 Km/h
V₈₅ = 63 Km/h

m = 56.5 Km/h
Δ = 9.1 Km/h
V = 46.1
Vₘᵢₙ = 45 Km/h
Vₘₐₓ = 85 Km/h
Problem was that registration had to be finished during the end of December.

In mentioned period 27 serious traffic conflicts have been registered. Those conflicts are presented in diagram of traffic conflicts, in figure 4.

There were six types of conflicts. Number of conflicts of all types and volume of traffic flow on conflict routes are presented in figure 5.

As it is seen from figure 5 traffic conflict with the highest risk is conflict between vehicles on minor road; from the north in right direction and from the south in left turning. Conflict between vehicles on major road from east to west and pedestrians on western side of major road is conflict next to first one.

Analysing by the all traffic conflicts the next factors are recognised as main contributors:

- Too high level of speeds of the fastest vehicles, especially in the east-west direction and big differences in speeds of vehicles in the same traffic flow (of about 40 km/h),
- Uncontrolled crossing of pedestrians on very wide area of western side of major road,
- Stopping of vehicles on western side of major road, in east-west direction, in front of kiosk (object A in figure 1),
- Big differences in paths and curvatures of left turnings on the crossroad,
- Violation of the right of way on crossroad from the vehicles turning left, and
- Bad quality of public lighting.
FIGURE 4  TRAFFIC CONFLICT DIAGRAM

(B) MINOR ROAD

(A) MAJOR ROAD

MOTOR VEHICLE

PEDESTRIAN
According to that next (ergonomic) countermeasures for the crossroad are proposed:

- to introduce the organised (zebrá) crossing for pedestrians on the western side of major road and traffic light for regulation of that traffic flow,

- to remove BUS-stop, for west-east direction, from the position in front of to position behind the crossroad,

- to draw the horizontal signalisation on crossroad, especially leading lines for left turning,

- to reduce the speeds of the fastest vehicles. This way big differences between the speeds of vehicles would be decreased to the tolerable level,

- to extend duration of green phase for the south-north direction on minor road in common green time for minor road; (introduction of "post-phase clearing out " on the minor road),

- to improve of public lighting and

- to remove the kiosk for tobacco and newspapers.

In that case traffic conflict technique and driver performance measure have been used for the purpose of risk diagnosis.

Determined risk values for all conflict types could be base for comparison of before and after state too. That comparison is necessary for evaluation of proposed countermeasures.
**FIGURE 5 TRAFFIC CONFLICTS AND THEIR RISKS**

**TIME PERIOD**
3 h, 15 min  
(11:45 - 12:45, 13:10 - 14:10, 15:00 - 15:15, 18:30 - 19:30)

<table>
<thead>
<tr>
<th>NO</th>
<th>TYPE OF CONFLICT</th>
<th>SERIOUS CONFLICTS</th>
<th>TRAFFIC FLOW</th>
<th>RISK ( \times 10^3 ) = ( \frac{\text{CONFLICTS}}{\sqrt{Z_1 \cdot Z_2}} )</th>
</tr>
</thead>
</table>
| 1  | ![Conflict 1](image) | 2+1+1 | 2+1+1 | \( Z_1 = 43 \)  
                      |       |       | \( Z_2 = 168 \)  
                      |       |       | \( R_4 = \frac{4}{85} \times 10^3 = 47 \) |
| 2  | ![Conflict 2](image) | 3+3+4 | 3+3+4 | \( Z_1 = 334 \)  
                      |       |       | \( Z_2 = 1702 \)  
                      |       |       | \( R_4 = \frac{10}{753.9} \times 10^3 = 13.3 \) |
| 3  | ![Conflict 3](image) | 1     | 1     | \( Z_1 = 612 \)  
                      |       |       | \( Z_2 = 23 \)  
                      |       |       | \( R_5 = \frac{1}{118.6} \times 10^3 = 8.4 \) |
| 4  | ![Conflict 4](image) | 2+1+1  
                      | 2+1+1  
                      | \( Z_1 = 1278 \)  
                      |       |       | \( Z_2 = 1278 \)  
                      |       |       | \( R_5 = \frac{8}{1278} \times 10^3 = 6.3 \) |
| 5  | ![Conflict 5](image) | 2+1   | 2+1   | \( Z_1 = 556 \)  
                      |       |       | \( Z_2 = 556 \)  
                      |       |       | \( R_5 = \frac{3}{556} \times 10^3 = 5.4 \) |
| 6  | ![Conflict 6](image) | 1     | 1     | \( Z_1 = 1373 \)  
                      |       |       | \( Z_2 = 231 \)  
                      |       |       | \( R_6 = \frac{1}{563.2} \times 10^3 = 1.8 \) |

**Legend:**  
- --- ➔ MOTOR VEHICLE  
- --- ➔ PEDESTRIAN
First experiences with the application of traffic conflict technique

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Analysing traffic accidents is an important part of traffic safety work in Hungary as well as in other countries. It indicates the black spots concerning the places, types, causes etc. of accidents and the priorities needed in publicity work, education, traffic engineering and traffic regulations. We have realised however early in the seventies that there are some shortages of basing our work on accident analysis. These shortages were originated from rarity of accidents, incidental factors influencing accident severity, the fact that accident statistics is incomplete and that one can hardly bring to light the correct situation which led to an accident. Trying to understand the causes of traffic unsafety we tried to find methods to analyse the process of traffic behaviour being sure that the best way to understand the insufficiencies of the system was to analyse the process as it existed in real traffic. We have tried several ways to grasp the most relevant aspects observing road user behaviour systematically, measuring psychophysiological indicators of psychic and/or physiological load of the driver in different situations, studying information acquisition by means of eye-movement recorder, analysing road users' communication, etc. We met several types of traffic conflicts during this work and considered them a phenomenon which might be important for understanding the process of accident causation and as an indicator of the dangerousness of a traffic
manoeuvre or an intersection. Though traffic conflicts of different sorts have been analysed in some of our works, especially conflicts between pedestrians and vehicles, the so called traffic conflict technique has not been used in the Institute for Transport Sciences. Becoming familiar with the technique in the last few years it seemed to us useful to adapt and apply it for the practical study of different locations, for before-after studies, etc. I had the opportunity to learn the Swedish technique of traffic conflict observation in practice this year. This was the starting point for the first experiences and for training some assistants for the work. There was no time and possibility to make studies with far-reaching results. We can present only some preliminary data and express our remarks on the method as it came from the first experiences.

The conflict study

Six intersections were chosen in Budapest as we tried to obtain practice in conflict observation on different places. The intersections had relatively bad accident records. They differed in many respect: five of them were four-leg and one three-leg crossing, there was tram-traffic in four of them in some with stop, one of the crossroads was one-way road in two cases, there were pedestrian crossings in four of them, etc. All the six crossings were however without traffic light. Two observers collected conflict data for three hours in each of the intersections. The Swedish traffic conflict technique was used, obtaining TTC value on ground of estimating speeds and distances from the collision point. Borderline between conflicts and non-conflicts, serious and light conflicts was defined also according to this method. /1, 2/
The number of conflicts observed was 100 altogether during the 18 hours of observation. The distribution of the conflicts among the intersections was as follows:

<table>
<thead>
<tr>
<th>NAME OF THE CROSSING</th>
<th>LEGS</th>
<th>TRAM-CROSS.</th>
<th>CONFLICTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fehérvári-Bártfai</td>
<td>4</td>
<td>yes yes</td>
<td>34</td>
</tr>
<tr>
<td>Bartók-Bertalan</td>
<td>3</td>
<td>yes yes</td>
<td>25</td>
</tr>
<tr>
<td>Thököly-Amerikai</td>
<td>4</td>
<td>yes yes</td>
<td>24</td>
</tr>
<tr>
<td>Thököly-Cházár</td>
<td>4</td>
<td>yes yes</td>
<td>7</td>
</tr>
<tr>
<td>Népköztársaság-Csengery</td>
<td>4</td>
<td>no no</td>
<td>7</td>
</tr>
<tr>
<td>Népköztársaság-Szív</td>
<td>4</td>
<td>no no</td>
<td>3</td>
</tr>
</tbody>
</table>

There was a possibility to compare conflict data with injury accident data collected in the last ten years (1976-85) on the intersections concerned. There were 141 injury accidents in the six intersections during ten years. Unfortunately it was impossible to get statistics about the not-injury collisions on these places because of the incompleteness of data processing system of the insurance company. As far as we could inquire about it there were no profound changes in traffic environment on these intersections during this period. There were changes surely in traffic volume that might influence accident statistics but we could not estimate exactly the changes for such a long time.

Comparing accident and conflict numbers of the intersections concerned you can see a slight connection between the two (table 1). As we have only preliminary data influenced to some extent by the fact that the observers had very few previous practice in observing and coding conflicts, we did not count correlations.
Table 1. Connection between accident and conflict numbers of the intersections

There was a possibility to learn more about the accident concerned, i.e. their exact time, type, case, participants, etc. The type of accidents was characterized by placing the accidents in a system of types made by Jankó and Holló /3/. The system is based on the manoeuvre and direction of arrival of the conflicting traffic participants as well as the kind of traffic participants. Looking for the differences and similarities of accidents and traffic conflicts on a given intersection, we used the same system of types to characterize traffic conflicts. The system consists of ten main categories.
ACCIDENT CATEGORIES

1. Hitting from behind
   Collision of
2. - vehicles coming from opposite directions
3. - vehicles coming from the same direction
4. - turning vehicles coming from opposite directions
5. - straight going vehicles coming from intersecting directions
6. - turning vehicles coming from intersecting directions
7. Bumping against standing vehicle
8. Collision with bicycle
9. Miscellaneous
10. Running down pedestrians

All the main categories have 3-9 smaller, more precisely determined sub-groups, the accident types.
It might be an interesting question how much do the accidents and conflicts in an intersection belong to the same type.
Looking at the three intersections on which there were more than ten conflicts, we can see as follows /table 2./. Those types are presented here which more than 10% of accidents or conflicts belong to.

Table 2. The most frequent accident and conflict types

<table>
<thead>
<tr>
<th>PLACES</th>
<th>TYPES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>acc.</td>
</tr>
<tr>
<td>Bartók-Bertalan</td>
<td>61 %</td>
</tr>
<tr>
<td>/26 accidents, 25 conflicts/ confr.</td>
<td>40 %</td>
</tr>
<tr>
<td>Fehérvári-Bártfai</td>
<td>55 %</td>
</tr>
<tr>
<td>/20 accidents, 34 conflicts/ confr.</td>
<td>41 %</td>
</tr>
<tr>
<td>Thököly-Amerikai</td>
<td>63 %</td>
</tr>
<tr>
<td>/43 accidents, 24 conflicts/ confr.</td>
<td>52 %</td>
</tr>
</tbody>
</table>
KEY TO THE TYPES

1007 Running down a pedestrian on a pedestrian crossing
603 Collision of vehicles when one of them turns left
106 Hitting from behind when the first vehicle is braking
501 Collision of vehicles coming from crossing directions and going straight forward
1002 Running down a pedestrian near the bus or tram stop

One can see that the most frequent accident and conflict types are roughly the same in these intersections, though pedestrians are overrepresented in accidents and vehicles are overrepresented in conflicts. This trend seems to be common in all intersections observed we draw them therefore together on the next table (table 3.).

One can see that the largest differences between the proportion of accidents and conflicts are at the types where pedestrians are concerned. There are much more injury accidents in which one of the partners, i.e. the person injured is a pedestrian than you could forecast simply from the number of pedestrian conflicts. And there are many conflicts between vehicles which do not lead to accidents, at least not to injury ones.

In order to see the main trends even more clearly one can draw together the types as well into the larger categories (table 4.).

<table>
<thead>
<tr>
<th>CATEGORIES</th>
<th>NUMBER</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACCIDENT</td>
<td>CONFL.</td>
</tr>
<tr>
<td>1.</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>2.</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3.</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>4.</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>5.</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>6.</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>7.</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>8.</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>9.</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>10.</td>
<td>101</td>
<td>41</td>
</tr>
</tbody>
</table>

Table 4. The frequency of the main categories in the accidents and conflicts.
Table 3. The frequency of types in the accidents and conflicts
<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
<th>Accident</th>
<th>Conflict</th>
</tr>
</thead>
<tbody>
<tr>
<td>703</td>
<td></td>
<td>2 (1.4%)</td>
<td>6 (6%)</td>
</tr>
<tr>
<td>805</td>
<td></td>
<td>0</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>807</td>
<td></td>
<td>2 (1.4%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>808</td>
<td></td>
<td>6 (4%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>905</td>
<td></td>
<td>4 (3%)</td>
<td>1 (1%)</td>
</tr>
<tr>
<td>907</td>
<td></td>
<td>3 (2%)</td>
<td>0</td>
</tr>
<tr>
<td>1001</td>
<td></td>
<td>5 (4%)</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>1002</td>
<td></td>
<td>6 (4%)</td>
<td>2 (2%)</td>
</tr>
<tr>
<td>1007</td>
<td></td>
<td>63 (45%)</td>
<td>34 (34%)</td>
</tr>
<tr>
<td>1008</td>
<td></td>
<td>27 (19%)</td>
<td>2 (2%)</td>
</tr>
</tbody>
</table>

Table 3. The frequency of types in the accidents and conflicts (contd.)
Conclusions

The first experiences with the application of traffic conflict technique are promising. The present state of the technique is exact enough that one can learn to observe and code conflicts in a standard way. On the other hand it is open enough to the more complex, more subjective observations as additional ones as well.

The first step of application is to train the observers carefully. It was our impression that one can learn to estimate speeds quite correctly but it is more difficult to determine the correct place where the avoiding manoeuvre started. One has a more correct impression on the TTC value. We want to try to base our coding on speed and TTC value.

The unexpectedness of the event seemed to us to be an important aspect of the conflict. The formal conflict description holds good in some situations as there is a collision course and one of the partners makes an evasive action. But the observer's impression on the probability of collision is very different if the evasive action was made by the participant only who has to give way or if both made evasive actions or only the participant with the right of way, even if the TTC values are exactly the same. We should find the way to make some distinctions according to the observable unexpectedness of the different situations.

Conflict observations gave us an insight into the informal rules existing in the intersections observed. It might be part of the safety diagnosis concerning the places in the future.
It is documented by the preliminary data presented that the type of conflicts and the probability of injury accidents are closely related. It is essential to observe and code the seriousness of the conflicts not only on ground of TTC but also of probability of injury accidents or of seriousness of the accidents as it is made in the Holland technique.

REFERENCES


The Effects of a Varying Speed Limit at a Highway Junction

An example of the use of the TCT in Finland

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The Finnish traffic conflicts technique

In our definition, a conflict is a traffic situation, where in the beginning of the evasive action the time-to-collision (TTC) is 1.5 seconds or less. A conflict is a severe one, if the evasive action is uncontrolled. In addition, we define potential conflict situations which are quite close to conflicts but have a higher TTC than 1.5 seconds. According to the ICTCT calibration studies, our potential conflicts resemble the minor conflicts of other conflict techniques.

In our conflict studies we always count also traffic volumes and all forms of "unwanted behaviour" in addition to conflicts and potential conflict situations. Traffic volumes in different flows and for different road user categories are essential for calculating the risks for hazardous situations and for control purposes in before and after studies. Thus we can compare different locations and different study periods. The various forms of "unwanted" traffic behaviour (traffic violations, exceptional driving/walking routes etc.) are very useful for diagnostic purposes.

We nearly always use video at our conflict studies despite the higher costs. The video tapes are used for:
- checking the conflict and potential conflict scorings,
- traffic counts,
- calculation of speeds, waiting times etc.,
- tapes of collected conflicts (observer training, problem illustration for planners and decision makers).

The main applications of our TCT can be divided into two categories: 1) safety diagnosis of a location and 2) before and after study on the effects of some safety measure. Some examples of our recent conflict studies in both categories are listed below.

1) Safety diagnosis
   - various accident black spots
   - different types of pedestrian crossings
   - identification of possible minor safety measures for heavily trafficked highway junctions
2) Effect studies

- junctions of service stations
- identification of critical daily periods for the timing of a varying speed limit
- renewal of the road traffic law
- channelisation of highway junctions
- separation of bicyclists and pedestrians on their common path
- reconstruction of the main street of small towns
- different timing strategies for signal control at junctions with high pedestrian flows
- varying speed limit

The study on a varying speed limit is included in both categories, which is why it has been chosen as an example to be studied more closely.

Varying speed-limit - the before study

The Roads and Waterways Administration (RWA) in Finland has completed some studies of a varying speed limit. These studies have dealt with the opinions of the road users, their observance of the speed limit, and the speed limit's effect on speeds. The varying speed limit of these studies was located on road sections passing a school.

The results of these studies were quite satisfactory. The RWA decided to try the varying speed limit also at a highway junction. The junction selected for this experiment is on a heavily trafficked highway connecting the centre of Helsinki to some neighbouring towns. At the studied X-junction the minor road leads to a small town. The junction is shown in Figure 1.
The minor road has stop signs at the junction. The speed limit on the main road is 80 kmph. The main road is channelized at the junction, and has an additional lane southwards from the junction for about 100 metres. Both safety and capacity problems were known to exist at the junction, and especially for the drivers turning left from the minor road. As the highway is to be reconstructed within five years, the RWA hoped that the varying speed limit would be a sufficient but not too costly measure for improving the capacity and safety of the junction.

The purpose of the before study was, in addition to gathering data for the effect study, to identify the time periods when the speed limit should be 60 kmph instead of the usual 80 kmph.

On the basis of the RWA's information and our visits to the junction we decided on making the studies on workingdays at 7 - 9, 11 - 13 and 15.15 - 17.15. The following data were gathered at the field studies on two days:
- hazardous situations (conflicts and potential conflicts)
- vehicle speeds on the main road
- traffic volumes in different flows
- minor road service times
- "unwanted" traffic behaviour

The results of the before study are summarised in Figure 2. The measurement periods were divided in periods of fifteen minutes in order to identify the problem periods at the junction. The safety and capacity (left turns from the minor road) problems seemed to be concentrated on periods from 7.00 to 8.00, and from 15.45 to 16.45. Left turns were an essential part of the safety problem at the junction, as a left turning vehicle was involved in 60% of all hazardous situations observed.

The traffic volumes in the congested direction were also at their highest during the aforementioned periods. Because of this the mean speeds in the congested direction were quite low, approximately 64 kmph, during these periods.

Based on the results of the before study we recommended that the varying speed limit should be 60 kmph on workingdays from 7.00 to 8.00, and from 15.45 to 16.45, and otherwise 80 kmph. The RWA agreed upon our recommendations and implemented the varying speed limit signs at the junction in the summer of 1985.
Figure 2. Summary of the results of the before study.
The after study - the effects of the varying speed limit

The after studies were carried out in the beginning of October, 1985, exactly one year after the before studies. The measurement periods and days were the same.

Figure 3 shows the mean speeds and traffic volumes on the main road in both directions at the before and after studies.

Figure 3. Traffic volumes and mean speeds on the main road.
Traffic volumes on the main roads were approximately 13% higher at the after studies than during the before studies.

The mean speeds in the congested direction were always below 60 kmph during the 60 kmph speed limit periods. The speeds were 6 - 15 kmph lower than during the corresponding periods in the before studies. The speeds against the congested direction had not decreased as clearly. A part of the decrease (approximately 3 kmph) was due to the increase of traffic volumes. Interestingly, the high volumes caused a delay in the effect of the speed limit change during the afternoon periods. The nearly continuous platoon on the main road adapted its speed according to the just changed speed limit 10 - 15 minutes after the actual change.

During the periods when the speed limit remained 80 kmph even at the after studies the mean speeds in the southbound flow on the main road had increased. The increase was about 3 - 5 kmph during the periods 7.00 - 8.00 and 11.15 - 12.15 despite the slightly higher traffic volumes. The changes of the mean speeds in the northbound flow seem to follow the changes in traffic volumes.

The capacity of the junction in regard to the left turning flow from the minor road is, of course, highly dependent on the traffic volumes on the main road. Because of this, we plotted the minor road service times against the main road traffic volumes. This is shown in Figure 4. The main road volume was calculated as the sum of the northbound flow and half of the southbound flow. The southbound flow was halved on the basis of the additional lane in that direction. Each observation represents the data of a period of 30 minutes.

![Figure 4. Minor road service times and main road volumes.](image)
The four observations of the 60 kmph periods do not seem to differ from the 80 kmph observations when the clearly visible relation between the service times and main road volumes is taken into account.

We studied the number and risk of hazardous situations separately for the 60 kmph and 80 kmph (after study) periods. Table 1 shows the number of vehicles involved in hazardous situations, traffic volumes, and their ratio in different traffic flows for the periods with the 60 kmph speed limit during the after study.

The risk of hazardous situations was usually lower in the after studies. The risk decreases were significant in the northbound flow on the main road, and almost significant for the whole junction. During the after studies the risk was higher in the southbound flow on the main road than in the before studies, although not significantly.

The number of conflicts had decreased from 6 to 1 despite the higher traffic volumes.

Especially the number and risk of situations between a left turning vehicle from the minor road and a straight driving vehicle from the southern approach of the main road had decreased. Their number had decreased from 16 to 7.

Table 2 shows the corresponding figures for the periods with the same speed limit of 80 kmph during both before and after studies.

The number and risk of hazardous situations had increased during these periods. The risk increased significantly for the left turning vehicles from the minor road. The risk increase was almost significant for the southbound flow on the main road, and for the whole junction.

The risk increase was clearest for situations between a left turning vehicle from the minor road and a straight driving vehicle from the northern approach of the main road.

The number of hazardous situations had increased most during the periods from 8.00 - 9.00, during which the speeds in the southbound flow had also increased most.

Most of the safety problems at the junction are caused by the left turning traffic from the minor road, whatever the speed limit. Especially left turning lorries and buses caused problems. They accounted for 10 - 20 % of the vehicles but for almost 50 % of the hazardous situations. These heavy vehicles accelerate very slowly from standstill but according to our observations their drivers seemed also to take higher risks in regard to the main road traffic probably relying on their vehicles' greater mass.
Table 1. The number of vehicles involved in hazardous situations, total number of vehicles and their ratio at 7 - 8 am and 3.45 - 4.45 pm for different vehicle flows at the before and after studies.

<table>
<thead>
<tr>
<th>Vehicle flow</th>
<th>Hazardous situations (C)</th>
<th>Traffic volume (E)</th>
<th>Risk 100 C/E</th>
<th>Signif. of risk difference 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>MAIN ROAD, from south</td>
<td>26</td>
<td>15</td>
<td>3340</td>
<td>3578</td>
</tr>
<tr>
<td>- to the right</td>
<td>0</td>
<td>0</td>
<td>822</td>
<td>818</td>
</tr>
<tr>
<td>- straight</td>
<td>26</td>
<td>15</td>
<td>2514</td>
<td>2756</td>
</tr>
<tr>
<td>- to the left</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>MINOR ROAD, from east</td>
<td>31</td>
<td>24</td>
<td>880</td>
<td>1040</td>
</tr>
<tr>
<td>- to the right</td>
<td>4</td>
<td>4</td>
<td>208</td>
<td>310</td>
</tr>
<tr>
<td>- straight</td>
<td>1</td>
<td>3</td>
<td>70</td>
<td>164</td>
</tr>
<tr>
<td>- to the left</td>
<td>26</td>
<td>17</td>
<td>602</td>
<td>546</td>
</tr>
<tr>
<td>MAIN ROAD, from north</td>
<td>14</td>
<td>20</td>
<td>3040</td>
<td>3316</td>
</tr>
<tr>
<td>- to the right</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>- straight</td>
<td>12</td>
<td>18</td>
<td>2740</td>
<td>3002</td>
</tr>
<tr>
<td>- to the left</td>
<td>2</td>
<td>2</td>
<td>288</td>
<td>282</td>
</tr>
<tr>
<td>MINOR ROAD, from west</td>
<td>5</td>
<td>3</td>
<td>92</td>
<td>132</td>
</tr>
<tr>
<td>- to the right</td>
<td>0</td>
<td>0</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td>- straight</td>
<td>5</td>
<td>2</td>
<td>62</td>
<td>104</td>
</tr>
<tr>
<td>- to the left</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>TOTAL</td>
<td>76</td>
<td>62</td>
<td>7352</td>
<td>8066</td>
</tr>
</tbody>
</table>

1) * significance of risk difference 95 %, (*) 90 %
Table 2. The number of vehicles involved in hazardous situations, total number of vehicles and their ratio at other measurement hours than 7 - 8 am and 3.45 - 4.45 pm for different vehicle flows at the before and after studies.

<table>
<thead>
<tr>
<th>Vehicle flow</th>
<th>Hazardous situations (C)</th>
<th>Traffic volume (E)</th>
<th>Risk 100 C/E</th>
<th>Signif. of risk difference 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td><strong>MAIN ROAD, from south</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the right</td>
<td>12</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- straight</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the left</td>
<td>12</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4376</td>
<td>4856</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MINOR ROAD, from east</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the right</td>
<td>10</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- straight</td>
<td>2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the left</td>
<td>7</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1180</td>
<td>1224</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MAIN ROAD, from north</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the right</td>
<td>5</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- straight</td>
<td>2</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the left</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3192</td>
<td>3690</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>MINOR ROAD, from west</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the right</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- straight</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- to the left</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>140</td>
<td>180</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>28</td>
<td>52</td>
<td>8888</td>
<td>9950</td>
</tr>
</tbody>
</table>

1) * signifigance of risk difference 95 %, (*) 90 %
The additional lane provoked some forms of unusual behaviour during both before and after studies. Firstly, some of the vehicles in the southbound flow used the lane for overtakings, which caused also some hazardous situations at the end of the lane. Secondly, many of the left turning vehicles used the additional lane for accelerating after having crossed the both ordinary straight driving lanes on the main road. This type of behaviour is against traffic rules but in our opinion improves the safety and capacity of the junction.

The conclusions of the study are listed below:

1) The changes in the speed limit sign were seemingly observed quite well, although in the congested traffic the speed changes can be due to only some of the drivers observing the changed speed limit.

2) The lower speeds caused by the 60 kmph speed limit improved the safety of the junction.

3) The increase of the driving speeds on the main road during the 80 kmph periods caused an increase in the number and risk of hazardous situations.

4) The speed limit changes had no apparent effect on the capacity of the junction in regard to the left turning traffic from the minor road.

5) The additional lane for the southbound traffic after the junction seemed to improve the safety and capacity of the junction.

6) The left turning vehicles, and especially lorries and buses, caused most of the safety problems observed.

The results obtained in this study are not necessarily applicable to other junctions as such because of the unusual layout (additional lane). Furthermore, the after studies were carried out only six weeks after the instalment of the varying speed limit signs. Drivers probably adapt their behaviour according to the varying speed limit as they get used to it. That is why we have proposed to the RWA that the after studies should be carried out also in October, 1986.
Application of Traffic Conflicts for Intersection Hazards and Improvements

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Abstract

The traffic conflicts technique is emerging as a means of identifying safety hazards and evaluating improvements at road intersections. This paper is a research report on the usefulness of the technique as a practical method to improve intersection design and traffic control measures. For this research, traffic conflicts were measured on a composite scale of severity, using time to collision and risk of collision sub-scales. The focus of the research is on the viability of the technique, the effect of intersection improvements on the incidences of traffic conflicts, and accuracy of the technique for application.

The validity of the technique for application appears to depend on the degree of disaggregation of the data and the reliability of measurement. Statistically significant correlations occur using disaggregated conflict and accident data, particularly for left turn, right turn and crossing movements. Rear end and weaving categories do not show significant correlations.

A before and after study of selected intersections, which were subjected to improved traffic control, showed a statistically significant reduction of conflicts at 3 of 4 intersections with the installation of traffic signals. A left turn improvement and the installation of stop signs had non-conclusive effects on reducing conflicts.

It is concluded that the application of the technique is dependent on the reliability of observation and measurement of traffic conflicts. Consequently, a training schedule is being developed which aims for 85% reliability, using a combined objective/subjective scale.

Introduction

Two approaches are possible in evaluating the safety of intersections and the effect of improvements: analysis of accidents, or observing hazard induced behavior [1]. There are both conceptual and practical problems associated with using accidents and accident records, such as those related to predictability [2] [3] [4], regression-to-mean and accident migration phenomena [5] and inadequate reporting of accidents [6]. A relatively recent development is the suggestion of using traffic conflict behavior to assess the accident potential of urban intersections, and to evaluate intersection improvements. The traffic conflicts technique (TCT) as conceived and developed by Perkins and Harris [7] defined traffic conflicts as evasive actions characterized by vehicle weaving manoeuvres and brake light applications. Spicer [8] introduced a 5 point severity scale ranging from
precautionary manoeuvres to emergency action. Hayward [9] introduced the
time to collision (TTC) measure, defined as the time required for two
vehicles to collide if no evasive action is taken. More recently, addi-
tional extensions have been added; namely, the idea of proximity (closeness
of the vehicles at the moment of evasive action, usually measured in terms
of car lengths) and a subjectively observed level of conflict severity.

A traffic conflict or "near-miss" is currently defined as a "traffic
event involving two or more road users, in which one user performs some
unexpected action, such as an encroachment or a change in direction or
speed, that places another user in jeopardy of a collision unless an
evasive manoeuvre is undertaken."[10] Traffic conflicts are considered a
surrogate measure for accidents or a measure of propensity for accidents.
As such, much of the research on traffic conflicts is concerned with
validity as accident surrogate and reliability of measurement.[11] The
purpose of this research is to investigate the use of traffic conflicts as
a practical means to evaluate safety at intersections and intersection
improvements.

Study Objectives

The research objectives of the study are: (1) to assess the validity
of traffic conflicts for practical application, (2) to apply the concept to
evaluate intersection improvements by observing changes in traffic con-
flicts before and after the improvements, and (3) to assess the reliability
of measurement of traffic conflicts for widespread application.

Study Procedures

In all, 13 intersections in the Vancouver area were divided into three
sub-sets according to the above research objectives of validation, evalua-
tion of improvements and reliability. These are shown on table 1.

Each of the intersections was observed for sixteen hours on two con-
secutive weekdays with each day consisting of 3 observation periods:
7:30 a.m. - 10 a.m.; 11 a.m. - 1:30 p.m.; 3 p.m. - 6 p.m. A team of two
observers, after 3 days of training, were stationed in diagonally opposite
quadrants of the intersection and recorded traffic conflicts for each of 7
manoeuvre types: left turn/opposing, right turn, crossing, weaving, rear
end, left turn/crossing, and pedestrian.*

Measurement of traffic conflicts was by two scales:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.1 - 3.0</td>
<td>very small</td>
</tr>
<tr>
<td>2</td>
<td>1.6 - 2.0</td>
<td>moderate</td>
</tr>
<tr>
<td>3</td>
<td>1.1 - 1.5</td>
<td>high</td>
</tr>
<tr>
<td>4</td>
<td>0.0 - 1.0</td>
<td>very high</td>
</tr>
</tbody>
</table>

* For a full description of these types of conflicts, see reference [11].
Table 1. Study Intersections and Research Objectives

<table>
<thead>
<tr>
<th>No.</th>
<th>Intersection Name</th>
<th>Year of Field Observations</th>
<th>Traffic Control Type</th>
<th>Improvement Improvement Objective*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Granville/Drake</td>
<td>1984</td>
<td>4-leg stop sign</td>
<td>V, R</td>
</tr>
<tr>
<td>2</td>
<td>Heather/12th</td>
<td>1984/85</td>
<td>4-leg stop sign</td>
<td>V, R, R</td>
</tr>
<tr>
<td>3</td>
<td>Main/10th</td>
<td>1984</td>
<td>4-leg stop sign</td>
<td>V, R</td>
</tr>
<tr>
<td>4</td>
<td>41st/Blenheim</td>
<td>1984</td>
<td>4-leg stop sign</td>
<td>V, R</td>
</tr>
<tr>
<td>5</td>
<td>Granville/Drake</td>
<td>1985</td>
<td>4-leg stop sign</td>
<td>V, E, 2 phase signal</td>
</tr>
<tr>
<td>6</td>
<td>Seymour/Drake</td>
<td>1985</td>
<td>4-leg stop sign</td>
<td>V, E, 2 phase signal</td>
</tr>
<tr>
<td>7</td>
<td>Oak/S.W. Marine</td>
<td>1985</td>
<td>4-leg stop sign</td>
<td>V, E, 2 phase signal</td>
</tr>
<tr>
<td>8</td>
<td>S.W. Marine/Dunbar</td>
<td>1985</td>
<td>4-leg stop sign</td>
<td>V, E, 2 phase signal</td>
</tr>
<tr>
<td>9</td>
<td>Nanaimo/E. Hastings</td>
<td>1985</td>
<td>4-leg 2 phase signal</td>
<td>V, E, 2 phase signal + LT bay</td>
</tr>
<tr>
<td>10</td>
<td>2nd/Semiah</td>
<td>1985</td>
<td>4-leg no control stop sign</td>
<td>V, E</td>
</tr>
<tr>
<td>11</td>
<td>27th/Pladstone</td>
<td>1985</td>
<td>4-leg no control stop sign</td>
<td>V, E offset</td>
</tr>
<tr>
<td>12</td>
<td>Kingway/McMurray</td>
<td>1985</td>
<td>3-leg stop sign</td>
<td>V, R</td>
</tr>
<tr>
<td>13</td>
<td>Kingway/Salisbury</td>
<td>1984/85</td>
<td>4-leg ped signal</td>
<td>V, R, E</td>
</tr>
</tbody>
</table>

* V = Validation of Technique  
E = Evaluation of Improvements  
R = Reliability of Technique

The time to collision (TTC) was observed by designating time zones on each intersection approach and referencing these to intersection or roadside markings. Risk of collision (ROC) was a subjective category recorded by the observer which measured the imminence of collision, independent of the TTC. There is clearly a high inverse correlation between TTC and ROC, but there are instances where, because of the relative positioning of the vehicles or the geometrics involved, a low TTC may not necessarily carry with it a high probability of actual collision. These two scales were therefore combined to give a 4 category severity scale:
**Validation of Technique**

The validation of conflicts was made along two dimensions of the data: (1) variations among movements, with all intersections pooled and (2) variations among intersections, with all movements pooled. Statistical validation was tested respectively by the Pearson 'r' test and Spearman's rank correlation test. The field work for the validation was done over two seasons, 1984 and 1985, with different field crews. Supervisory personnel and training were consistent for each season. The result of the correlation analysis of higher severity* by movement categories, reported on separately for the 1984 data (4 intersections) and the 1985 data (9 intersections); and combined for all intersections, is given by table 2.

<table>
<thead>
<tr>
<th>Type of Conflict</th>
<th>Severity Levels</th>
<th>1984</th>
<th>1984/85</th>
<th>1985</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$r_c$</td>
<td>$a$</td>
<td>$a$</td>
</tr>
<tr>
<td>Left Turn Opposing</td>
<td>4.4 - 4.2</td>
<td>0.91</td>
<td>0.35</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.95</td>
<td>0.66</td>
<td>0.94</td>
</tr>
<tr>
<td>Right Turn</td>
<td>4.4 - 4.2</td>
<td>0.66</td>
<td>0.35</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.93</td>
<td>0.61</td>
<td>0.87</td>
</tr>
<tr>
<td>Crossing</td>
<td>4.4 - 4.2</td>
<td>0.10</td>
<td>0.57</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.73</td>
<td>0.78</td>
<td>0.82</td>
</tr>
<tr>
<td>Weaving</td>
<td>4.4 - 4.2</td>
<td>0.00</td>
<td>0.42</td>
<td>0.38</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.00</td>
<td>0.40</td>
<td>0.34</td>
</tr>
<tr>
<td>Rear End</td>
<td>4.4 - 4.2</td>
<td>1.00</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.97</td>
<td>0.17</td>
<td>0.08</td>
</tr>
<tr>
<td>Left Turn Crossing</td>
<td>4.4 - 4.2</td>
<td>0.40</td>
<td>0.68</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.57</td>
<td>0.75</td>
<td>0.78</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>4.4 - 4.2</td>
<td>1.00</td>
<td>0.70</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.98</td>
<td>0.72</td>
<td>0.85</td>
</tr>
<tr>
<td>Total</td>
<td>4.4 - 4.2</td>
<td>0.40</td>
<td>0.28</td>
<td>0.39</td>
</tr>
<tr>
<td></td>
<td>4.4 - 3.2</td>
<td>0.59</td>
<td>0.39</td>
<td>0.38</td>
</tr>
</tbody>
</table>

* The research over the two seasons have consistently shown a higher correlation of accidents with high and very high severity conflicts than when lower severities have been included. This range (4.4 - 3.2) incorporates a threshold of a 1.5 sec. TTC and "moderate" ROC.
Making the appropriate assumptions of normal distributions, independence of variables and linearity, the coefficients of correlation as shown by Table 2 reflect statistical significance between conflicts and accidents for left turn/opposing and pedestrian movements for all data sets. Examining the larger data set (n=13), the right turn crossing and left turn/crossing also are significantly related. The tests appear to show that weaving and rear end conflicts are fairly conclusively not associated with accidents in those categories. The 1985 data set produced a higher level of confidence of association than the 1984 data set, partly because of the increased sample size, and partly because of more observer skill in recognizing conflicts from precautionary movements.

For the above results the relationship between conflicts and accidents was found by combining the data for all intersections without regard to the similarity or dissimilarity of the intersections. Differences in geometry, traffic control features, traffic and pedestrian volumes, and land use patterns may have significant effects on a particular type of traffic conflict. Individual characteristics of each intersection were taken into consideration by analyzing the relationship between conflicts and accidents collected at each intersection separately, with the results given by Table 3. All but 3 show statistical correlation.

Table 3. Results of Regression Analysis of Individual Intersection for the Severity Range 4.4 - 3.2

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Year</th>
<th>r_c</th>
<th>0.05</th>
<th>0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heather &amp; 12th Ave.</td>
<td>1984</td>
<td>0.49</td>
<td>0.62</td>
<td></td>
</tr>
<tr>
<td>Granville &amp; Drake</td>
<td>1984</td>
<td>0.90</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Main &amp; 10th Ave.</td>
<td>1984</td>
<td>0.80</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>Blenheim &amp; 41st Ave.</td>
<td>1984</td>
<td>0.82</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>Oak &amp; S.W. Marine Dr.</td>
<td>1985</td>
<td>0.87</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Granville &amp; Drake</td>
<td>1985</td>
<td>0.87</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Seymour &amp; Drake</td>
<td>1985</td>
<td>0.90</td>
<td>0.90</td>
<td></td>
</tr>
<tr>
<td>Dunbar &amp; S.W. Marine Dr.</td>
<td>1985</td>
<td>0.46</td>
<td>0.46</td>
<td></td>
</tr>
<tr>
<td>Nanaimo &amp; Hastings</td>
<td>1985</td>
<td>0.87</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>Semlin &amp; 2nd Ave.</td>
<td>1985</td>
<td>0.09</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>Gladstone &amp; 27th Ave.</td>
<td>1985</td>
<td>0.99</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>McNicoll &amp; Kingsway</td>
<td>1985</td>
<td>0.92</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Salisbury &amp; Kingsway</td>
<td>1985</td>
<td>0.75</td>
<td>0.75</td>
<td></td>
</tr>
</tbody>
</table>

The Spearman rank correlation coefficient, r_s, obtained for the thirteen intersections ranges from 0.77 to 1.00 (r_s critical for α = 0.051, n = 13 is .481) (Table 4). These indicate that the association between ranking an intersection by conflicts compared to ranking by accidents, is statistically significant. To be able to rank intersections by hazard would be particularly useful for evaluating "new" intersections or recent changes to an existing intersection.
Table 4. Results of Analysis of Ranking Critical Movement by Conflicts and Past Accidents

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Year</th>
<th>Spearman Rank Correlation Coefficient, $r_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heather &amp; 12th Ave.</td>
<td>1984</td>
<td>0.79</td>
</tr>
<tr>
<td>Granville &amp; Drake</td>
<td>1984</td>
<td>0.96</td>
</tr>
<tr>
<td>Main &amp; 10th Ave.</td>
<td>1984</td>
<td>0.85</td>
</tr>
<tr>
<td>Blenheim &amp; 41st Ave.</td>
<td>1984</td>
<td>0.77</td>
</tr>
<tr>
<td>Oak &amp; S.W. Marine Dr.</td>
<td>1985</td>
<td>0.89</td>
</tr>
<tr>
<td>Granville &amp; Drake</td>
<td>1985</td>
<td>0.78</td>
</tr>
<tr>
<td>Seymour &amp; Drake</td>
<td>1985</td>
<td>0.82</td>
</tr>
<tr>
<td>Dunbar &amp; S.W. Marine Dr.</td>
<td>1985</td>
<td>0.78</td>
</tr>
<tr>
<td>Nanaimo &amp; Hastings</td>
<td>1985</td>
<td>0.78</td>
</tr>
<tr>
<td>Semlin &amp; 2nd Ave.</td>
<td>1985</td>
<td>0.96</td>
</tr>
<tr>
<td>Glenmore &amp; 27th Ave.</td>
<td>1985</td>
<td>1.00</td>
</tr>
<tr>
<td>McMurray &amp; Kingway</td>
<td>1985</td>
<td>0.78</td>
</tr>
<tr>
<td>Salisbury &amp; Kingway</td>
<td>1985</td>
<td>0.82</td>
</tr>
</tbody>
</table>

Results of Before and After Study

A before and after study was done on seven of the 13 intersections. Four intersections were subjected to signal improvements, one had a left turn bay added, and two were improved by stop signs on the minor approach. Results show, in general, a decrease in conflicts with the improvement (table 5). Detailed results from the before and after study are contained in [12] and are summarized below.

For the four intersections subjected to signalization there is a reduction in crossing and left turn/crossing conflicts. However, in one case, Granville and Drake, there is a substantial increase in left turn/opposing conflicts. Also, there is a decrease in rear end conflicts (although somewhat marginal at Dunbar and S.W. Marine). As a general observation, the movements with the most accidents have the greatest decrease in conflicts (except for the LT/O at Granville and Drake).

Two intersections, Nanaimo at Hastings and Semlin at 22nd Ave., were improved by approach left turn bays, and by stop signs, respectively. At the former intersection, total conflicts actually increased, mostly due to LT/O, but severe conflicts decreased from 11 to 2 with the major reduction in rear end conflicts (-56% in the high severity category). The increase in the LT/O movement may be due to a migration of left turning traffic to the intersection due to the introduction of the left turn bay, and/or by unfamiliarity with the use of the left turn bay. The effects of the stop sign installation are not considered conclusive. A second stop sign example had so few conflicts that it is not reported on here.
Table 5. Before and After Conflicts by Movement Type and Severity Levels for Intersections Improved by Traffic Signals

<table>
<thead>
<tr>
<th>Before Traffic Signals</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Severity Levels</strong></td>
<td>4.2</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>LTO</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RT</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>W</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>RE</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>LTC</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>P</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>79</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>After Traffic Signals</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Severity Levels</strong></td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>4.4</td>
<td>4.4</td>
</tr>
<tr>
<td>LTO</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RT</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>W</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>RE</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>LTC</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>P</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>14</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>Before Traffic Signals</th>
<th>Day 1</th>
<th>Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak &amp; S.W.Marine</td>
<td>LTO</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>W</td>
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<td>4</td>
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<tr>
<td></td>
<td>RE</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>LTC</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>24</td>
<td>79</td>
</tr>
<tr>
<td>Cranville &amp; Drake</td>
<td>LTO</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>RE</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LTC</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>11</td>
<td>70</td>
</tr>
<tr>
<td>Seymour &amp; Drake</td>
<td>LTO</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>RE</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>LTC</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>17</td>
<td>38</td>
</tr>
<tr>
<td>Dunbar &amp; S.W.Marine</td>
<td>LTO</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>W</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>RE</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>LTC</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>P</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>7</td>
<td>44</td>
</tr>
</tbody>
</table>
Resources did not permit an extensive control study, nor the measurement of traffic flows at the subject intersections. However, it was deemed necessary to establish some baseline reference to evaluate findings. Consequently, two intersections with no improvements were measured a second time: Heather and 12th (which had been studied in 1984) and Kingsway and Salisbury. The latter intersection was recorded by the same observers at two different dates in 1985 and show a reasonable consistency in traffic conflicts. However, results at Heather and 12th recorded 1985 conflicts consistently lower than 1984 ones.

The 't' test was applied to the data to determine the statistical significance of the before and after changes in conflict. Table 6 shows that the signal installation at three of the four intersections causes a significant drop in conflicts. The other improvements show not significant results.

Table 6. Result of 't' Test of Before and After Improvement by Intersection

<table>
<thead>
<tr>
<th>Intersection</th>
<th>Improvement</th>
<th>'t'</th>
<th>S/NS at tα = 1.943*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak &amp; S.W. Marine</td>
<td>Signal</td>
<td>3.14</td>
<td>S</td>
</tr>
<tr>
<td>Granville &amp; Drake</td>
<td>Signal</td>
<td>2.13</td>
<td>S</td>
</tr>
<tr>
<td>Seymour &amp; Drake</td>
<td>Signal</td>
<td>3.33</td>
<td>S</td>
</tr>
<tr>
<td>Dunbar &amp; S.W. Marine</td>
<td>Signal</td>
<td>1.78</td>
<td>NS</td>
</tr>
<tr>
<td>Nanaimo &amp; Hastings</td>
<td>L.T. Lane</td>
<td>0.27</td>
<td>NS</td>
</tr>
<tr>
<td>Semlin &amp; 2nd Ave.</td>
<td>Stop Sign</td>
<td>1.42</td>
<td>NS</td>
</tr>
</tbody>
</table>

*a S = significant difference at 95% level of confidence (α .05)
NS = not significant

When the results of the four intersections subject to signal installation are pooled, results show that the signal installation significantly influenced a reduction in conflicts for right turn, crossing, rear end, and left turn/crossing movements (table 7).

Table 7. Result of 't' Test of Before and After Signal Installation by Movement Types

<table>
<thead>
<tr>
<th>Movement Type</th>
<th>'t'</th>
<th>S/NS at tα = 2.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTO</td>
<td>-0.43</td>
<td>NS</td>
</tr>
<tr>
<td>RT</td>
<td>3.88</td>
<td>S</td>
</tr>
<tr>
<td>C</td>
<td>3.46</td>
<td>S</td>
</tr>
<tr>
<td>W</td>
<td>1.24</td>
<td>NS</td>
</tr>
<tr>
<td>RE</td>
<td>3.20</td>
<td>S</td>
</tr>
<tr>
<td>LTC</td>
<td>6.29</td>
<td>S</td>
</tr>
<tr>
<td>P</td>
<td>2.30</td>
<td>NS</td>
</tr>
</tbody>
</table>
Reliability

As expected, the 't' test of changes in the 'control' intersections showed that at Heather and 12th the change between the two observations was significant, whereas for Kingsway at Salisbury the change was not significant. The results for Heather and 12th must be interpreted with caution owing to the use of different observers whose training was not identical (the 1985 observers benefitted from an additional year's experience by the UBC team in training and observation methods, whereas in 1984 everyone was learning the procedure).

Our observers were trained over a period of 3 days, using videotape recordings at the training locations as a criterion set of observations. A 75% reliability was observed after 3 days at which time the observers were given field assignments. Four intersections were recorded in 1984. In 1985 a different team went through the same training period and recorded traffic conflicts for a further 9 intersections. One intersection was repeated the 2nd year (Heather and 12th).

In analyzing the results of the two studies for correlation of conflicts with accidents, it became clear that measurement of the conflicts was a factor in applying the technique. The number of conflicts recorded at the intersections studied in 1985 were consistently lower than those recorded in 1984, including the repeated intersection (figure 1). Results from the two 'control' intersections, one which was done by two different teams in two different years, compared with one done by the same team at two different times in the same year, showed a relative difference of 0.88 and -0.10 respectively in conflicts recorded.* On investigation, it was clear that the measurement of conflicts was more precise in 1985, attributable in large part to the recognition of precautionary manoeuvres.

A further study was undertaken to test reliability of measurement of the incidence and the severity of conflicts. Three teams of pairs of observers were selected and tested for time dependent reliability. Members of each team observed conflicts at a common intersection over 2 hours per day in conjunction with an overhead video recorder. Their observations and recording of conflict severity levels on a 3 point TTC/ROC scale were then compared with the video recording and debriefing took place with the objective of improving the reliability from day to day. The schedule was as follows:

<table>
<thead>
<tr>
<th>Team</th>
<th>Continuous Observation Period (days)</th>
<th>Layoff Period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

* $2(B-A)/(A+B)$: where B is before and A is after.
Figure 1. Regression - Accidents/Conflicts: Pooled Movements

Figure 2. Traffic Conflict Identification
Preliminary analysis indicates the following tentative results as shown on fig. 2. Firstly, about 77% reliability was reached after 5 days, with no substantial improvement after that. In fact, accuracy of recording fluctuated dramatically during the second 5 day period. Secondly, a lay-off period reduced the accuracy of observation when the observer returned, but accuracy increased quickly to the final levels, obtained before the lay-off. (Results for conflict severity identification are similar.) A concern shown by the results is the decreased stability during a protracted period of observation. This cannot be explained at this time, but two suggestions are the onset of boredom and inclement weather. The use of the same intersection for testing the observational skills of highly intelligent students over 10 days may have induced a certain boredom. Also, seasonal record low temperatures and rain may have affected the test results. More research and analysis is necessary before any substantive conclusions can be reached on these results.

Conclusions

While an accident is perhaps the definitive evidence of roadway hazard, accident records need to be complemented by a measure of hazard which is anticipatory and potentially predictable. The research results above, it is hoped, contribute to the knowledge of traffic conflicts and their usefulness. However, the research points to the need to refine the measure of conflict severity to make it a reliable instrument for hazard evaluation and roadway improvement.

Acknowledgments

The Insurance Corporation of British Columbia sponsored the research. Peter Cooper of ICBC co-authored a previous paper on the results of the before and after study, some of which are summarized here. His contribution is highly appreciated and acknowledged. Of course, the author accepts all responsibility.

References


THE USAGE OF TRAFFIC CONFLICT TECHNIQUE ON THE SWEDISH NATIONAL ROAD NETWORK

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1. BACKGROUND

For the purpose of unvaryingly pointing out and analysing black-spots on roads, the Swedish National Road Administration (SNRA) developed a model for the work to be carried out on regional traffic safety at the end of the 70's. This model titled "The Regional Road Administration Work on Traffic Safety" was published in a report dated 1978 (1). The contents, in general, is as follows:

- methods for pointing out blackspots on a specific road network through systematically analysing accidents reported by the police
- methods for recognizing and obtaining information on locations considered dangerous from a traffic point of view, but where no accidents have been reported by the police
- methods for analysing these locations pointed out in order to find the measures suitable for attending to the problem
- methods for establishing priorities on the locations analysed with respect to the gain in traffic safety, the cost, etc.

Using the model, there are generally no difficulties in locating places with traffic safety problems.

The difficulties arise when making an analysis of the blackspots in order to find a suitable solution.

The number of accidents registered by the police in the Swedish national road network at the locations pointed out is often low. This makes it difficult to choose relevant measures for the improvement of traffic safety.

Another problem with small accident figures arises when setting priorities between several different objects. Priorities are given according to the estimated gain in traffic safety, directly dependant on the number of accidents which have accured and the assumed effect of the measures choosen.

In order to be able to deal with this problems it is often necessary to supplement the accident data with other data.
2. THE INTRODUCTION OF CONFLICT TECHNIQUE

For the SNRA the conflict technique developed at the Lund Institute of Technology was considered as an interesting and possible method in the future within the regional traffic safety work.

Before introducing the conflict technique at the SNRA there were two main problems to deal with.

Firstly, the conflict technique was developed primarily for studies in built-up-areas where the velocity is generally low (50 km/h). For the SNRA the main interest is to use the conflict technique in rural areas which is the predominant environment within the Swedish national road network.

Secondly, a training program was to be produced for the personnel within the 24 Regional Road Administrations (RRA) spread all over the country.

In 1978 the SNRA started a project at the Lund Institute of Technology for the purpose of adapting the already existent conflict technique to the usage in rural conditions.

The first stage of the project showed that the existing urban conflict technique was suitable for rural conditions as well, but with one, very important reservation. The fixed limit value used to judge the degree of seriousness of a conflict in urban areas, 1.5 seconds, had to be changed to a value depending on the velocity.

The figure at next page indicates how this limit value varies with the velocity and the distance to an estimated point of collision.

A more detailed description of the urban technique is given in reference (2).

Moreover, it can be mentioned that the relation between conflicts and accidents indicated in the urban technique was not generally considered to be representative of the national road network as a whole.

The second stage in the project was to produce a training program for personnel at the Regional Road Administrations.

An instruction manual in conflict studies was drawn up based on the experiences gained from completed courses, performed conflict studies, etc, at the Lund Institute of Technology.

In 1982 a summing-up of the project was presented in a report (3).

During 1982 some thirty representatives of the Regional Road Administrations were trained in the conflict technique for one week. The education included both theory and field studies.

The education was followed up by an inquiry to each participant. One question asked was if the participants thought that they should carry out conflict studies in 1983. They all answered yes.
THE LIMIT VALUE BETWEEN SERIOUS AND NON-SERIOUS CONFLICTS AND ITS VARIATION WITH THE VELOCITY AND THE DISTANCE TO AN ESTIMATED POINT OF COLLISION

All situations above the broken line are to be registered.
3. THE PRESENT SITUATION

So far only about ten conflict studies have been carried out within the 24 regional organizations.

The question we have to ask is, "Why have only a few studies been carried out during the last three years?"

The Head Office of the SNRA has not made any stipulations as to the usage of the traffic conflict technique. Each Regional Road Administration can independently make its own decision from case to case.

Any lack of education or other help can hardly be the reason.

In addition to the education, advisory consultation both from the Head Office of the SNRA and from the Lund Institute of Technology has been possible. The instruction manual and a film containing information and exercises on the conflict technique are other aids to make studies easier.

Different inquiries to the personnel working with the traffic safety model have shown that the technique of today has too great of a demand on resources.

At an average intersection on the Swedish rural network the daily incoming traffic is about 5000 vehicles, of which 5-10% are from the secondary roads.

When planning conflict studies for the basis of selecting a precaution, the manual gives a value of 10-20 serious conflicts. This is equivalent to an observation time of at least 80 hours with at least 2 men, i.e. at least 160 man hours at an average intersection. Personnel that are qualified for such assignments at the respective Regional Road Administrations have numerous different tasks which is why it is very difficult to allot time for such extensive studies. Furthermore, the financial resources for traffic safety work are inadequate in order to use consultants to any greater extent.

4. THE FUTURE

After a reorganization of the SNRA this year the significance of the traffic safety work has increased.

Consequently, it can be taken for granted that the traffic conflict technique will be a factor in the work on traffic safety within the SNRA in the future.

There are, however, three main problems to solve before the technique more continuously can be used within the traffic safety work at the SNRA

1. The technique must be developed in order to suit the demands of the SNRA i.e. adaption to studies in parts of the country with low traffic volume

2. Studies concerning the relationship between conflicts and accidents

3. The organization of the work for conflict studies
As mentioned earlier, the present technique is very demanding on the resources pertaining to the studies on the Swedish Rural Network. One study could often extend over several weeks. One way to solve this problem could be some type of automatic registration of conflicts by means of a computer. By working with video recordings with the help of a computer or data from detectors in the road, a certain portion of the assessment which is today done manually by an observer, could be replaced. The best way would be to let the computer work with certain calculations referring to conflicting traffic and make its own decisions when video recording so that only potential conflict situations are recorded. Later the observer could assess and analyse the incidents directly from the video film.

The amount of time used for studies at places where there is little traffic could thereby be considerably reduced making the use of the conflict technique less expensive and reducing the number of personnel needed which in turn would make the technique more attractive to use.

As a conclusive goal one can speculate about a fully automatic registration and analysis instrument that achieves the analysing an observer does today.

To show what benefits different traffic safety precautions offer, the SNRA uses financial estimate tables. The advantages or benefits are expressed as a value of expected accident reduction in comparison to the invested capital for a certain precaution.

Depending on, among other things, the few studies that have been carried out in a rural environment today, the connection between conflicts and accidents is missing. The validness of the technique referring to conflicts - accidents will, however, probably be very expensive. Earlier estimates reach the million mark.

Still this knowledge can gradually be increased by more general use of the conflict technique and experiance gained from it.

The situation today is that the Regional Road Administrations will hardly carry out any studies on their own. The knowledge that has already been gained often has not been maintained by regular studies. Furthermore, newly-employed personnel have not been educated with this knowledge.

There are two alternatives for the continued work on conflict studies.

a) Carry out a new period of education for newly-employed personnel and refresher courses for those who completed the education offered in 1982.

b) Relieve the RRA's work burden and instead form a central group at the head office to carry out conflict studies commissioned by the RRA.

Experience shows that despite a first-rate education in conflict technique, it has not been used regularly within the RRA. Therefore knowledge has worsened and refresher courses are now needed at many RRAs before studies can be carried out.

Since additional resources - personnel and/or financial - will probably not be granted to the RRA despite revised education, the conflict studies are not likely to be carried out to any great extent.
Instead, the possibility of organizing a group centrally is being discussed within the head office. The group would consist of a number of qualified conflict observers which would carry out studies commissioned by the RRA and work in co-operation with them. The group would primarily carry out field studies but would also help with a portion of the analysis if so desired.

By means of a central group, uniform assessment could be achieved regardless of where in Sweden. This gives a more homogenous and reliable material for, among other things, to find the validity of the technique as well as the evaluation of the precaution/effect connection. Still another advantage with a central group is that the financial resources for technical equipment can be concentrated to the group instead of spreading it over 24 Regional Road Administrations. The chances for a faster development of the technical equipment is thereby increased.

5. CONCLUSIONS

In summary, the following conclusions can be drawn on the usage of the traffic conflict technique in the SNRA traffic safety work

- We consider it essential that the conflict technique will be used within the traffic safety work in the rural network as a complement to the accident data.
- The carrying out of studies should be performed by a central group at the head office in co-operation with the respective RRAs.
- The technique must continue to be developed so fewer resources are used for studies at places with little traffic volume.
- The connection between conflicts and accidents in rural conditions must be more carefully researched.

REFERENCES

ABSTRACT

In the late 1970's the Swedish National Road Administration (SNRA) developed a traffic safety work model for their regional organization. The model shows, based on reported accidents from the police, places with high accident risks i.e. black spots.

This paper describes the work on introducing the traffic conflict technique, developed at the Lund Institute of Technology, to the Regional Road Administrations (RRA).

One part of the traffic safety work recommends that conflict studies should be carried out with the intention to get a better decisionground for taking measures.

In the early 1980's the staff in all 24 regional road administrations was educated in the traffic conflict technique. The education lasted one week and 6-8 persons took part each time.

The SNRA has not made any stipulations as to the usage of the traffic conflict technique. Each regional road administration can independently make its own decision from case to case as to the performance of a prospective conflict study.

Until today there have been only about 10 conflict studies carried out at the regional road administrations. The reasons why so few studies have been carried out are that the technique of today demands a lot of resources and that you loose the knowledge of the technique since it's not used regularly.

After a reorganization of the SNRA this year the significance of the traffic safety work has increased. The question about where to place the conflict technique within the traffic safety work is being discussed over again.

Three main problems must be solved before the technique continuously can be used.

1) The technique must be developed in order to suit the demands of the SNRA so it can be used in parts of the country with low traffic volume.

2) The relationship between conflicts and accidents,

3) The organisation of the work for conflict studies.
APPLICATION OF TRAFFIC CONFLICT TECHNIQUES IN AUSTRIA

RALF RISSE.

Up to now traffic conflict technique in Austria was used in three areas:

- Modification of dangerous spots in the road network (Vienna city highway, network of transit roads through Austria; using on-the-spot-observations).
- Quantitative and qualitative description of performance of individuals and analysis of the validity of indoor-test data, referring to the driving behavior as a criterion (using observations out of the subjects' cars).
- Description of the behavior of groups of traffic participants.

Diagnosis and Modification of Dangerous Spots

For the diagnosis and structural modification of dangerous spots in the road network we use on-the-spot-observations, collecting as many data as possible about the behavior of the involved subjects before the conflicts, thus trying to get some information about the traffic-conflicts' causes. As most important we consider the question, if the so-called "evasive action" is a reaction to an unexpected act of other road participants or part of a misleading communication process, thus probably not representing a real traffic-conflict (though, maybe, a conflict in the sociological meaning).

Individual Driving Performance

In order to be able to judge individual driving performance, data concerning the following variables were to be collected (out of the subject's car):

- Communication processes with other road-users
- Erroneous behavior
- Traffic-conflicts

Communication Processes

are defined as action-reaction-chains to clarify a situation, without the efforts of the traffic participants necessarily being
successful; it is possible, within a communication process, that one traffic participant forces the other one to set an evasive action in order to prevent an accident. It is up to the observer, though, to decide, if a reaction is an expected consequence for the reacting person or if it resulted of a behavior not to be expected, thus being a real emergency action.

Erroneous Behavior

Searching for types of behavior which lead to traffic conflicts, or to accidents one would expect an accident to have been preceded by dangerous behavior (e.g., behavior that left no safety margin or behavior that left the outcome to chance, thus increasing the probability of an accident). As a rule, behavior not consonant with traffic regulations is at the same time dangerous behavior, e.g., ignoring a red-traffic light within the confines of urban areas where structures impede the field of vision is indeed always dangerous. But there are situations where illegal behavior does not seem to be dangerous: As an example one has only to think of speeding on an empty and clean two or three lane road. If, when trying to identify types of behavior which lead to accidents one will have to consider both legality as well as the degree of danger coincident to any certain behavior as two important aspects.

A third aspect certainly is the ability of road-users to communicate with other road-users in a way that excludes misunderstandings, including the ability to recognize the intention of others: Behavior that leads to misunderstandings or behavior that is caused by misunderstanding most probably represents danger.

Traffic conflicts appear as a consequence of erroneous behavior of either the observed subject or another traffic participant. This statement is not to be seen as an axiom: In some cases there certainly are structural reasons for traffic conflicts without the conflict itself being the fault of one of the traffic participants. But we don't think that this is the rule.
Erroneous behavior and traffic conflicts - to be observed roughly in a ratio of ten to one - are approximately poisson distributed. Taking that kind of distribution into consideration we developed, in Vienna, a probabilistic model in order to compare different amounts of critical events. It showed, that the amount of conflicts which a subject gets involved in correlates with some variables of the driver record as well as with other behavioral data.

Table 1  Correlations between conflicts, accident-record and other behavioral variables collected during the test ride.

<table>
<thead>
<tr>
<th>traffic-conflicts on the ride</th>
<th>accident record</th>
<th>unfriendly communication</th>
<th>erroneous behavior of the observed subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>.2++</td>
<td>.3++</td>
<td>.4++</td>
<td></td>
</tr>
</tbody>
</table>

++: $\alpha \leq 0.01$

Table 2  Distribution of traffic conflicts in reference to "driving marks" agreed on by two observers ("1" being "very good" and "5" being "very bad" driving performance).

<table>
<thead>
<tr>
<th>Mark</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>traffic-conflicts on the ride</td>
<td>.6</td>
<td>1.1</td>
<td>2.1</td>
<td>2.7</td>
<td>7.3</td>
</tr>
</tbody>
</table>

We also could find and prove relations between the results of the test-rides and some results of the indoor-testing.

Table 3  Correlations between the amount of traffic-conflicts during the test ride and some test variables.

<table>
<thead>
<tr>
<th>Traffic-conflicts during the test-ride</th>
<th>indoor-testing-variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>.15+</td>
<td>peripherical-visual task</td>
</tr>
<tr>
<td>.17+</td>
<td>reaction task</td>
</tr>
<tr>
<td>.17+</td>
<td>concentration task</td>
</tr>
<tr>
<td>.15+</td>
<td>sensomotorial task</td>
</tr>
</tbody>
</table>

+: $\alpha \leq 0.05$
Typical Behavior of Groups of Traffic Participants

Using observations out of the subject's car it is possible to find characteristic types of behavior of groups of traffic participants - of course the sample has to be big enough.

A very important element of behavior is the solution of conflicts: E.g., which evasive action is set and by whom is the evasive action set in order to prevent a conflict from being transformed into an accident.

For example, looking at elderly car-drivers, we found out that in comparison to other age groups their participation in solving conflicts is quite low (see table 4).

Table 4 Percentage of participation in solving the traffic-conflicts an individual is involved in

<table>
<thead>
<tr>
<th>Age</th>
<th>18-24</th>
<th>25-34</th>
<th>35-44</th>
<th>45-59</th>
<th>60-</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of participation in conflict-solving</td>
<td>70</td>
<td>80</td>
<td>79</td>
<td>70</td>
<td>38</td>
</tr>
</tbody>
</table>

This result caused some follow-up studies in Vienna, the aim of which is to find out the reasons for the decreasing participation in conflict solving specially, and maybe in problem solving generally, of elderly road users.
V. EVALUATION OF TRAFFIC CONFLICT TECHNIQUES

Oppe, Siem  Evaluation of traffic conflict techniques

Hyden, Christer  Evaluation of TCT:s, validation results

Garder, Per  Theory for 'strong' validation
EVALUATION OF TRAFFIC CONFLICT TECHNIQUES

S. Oppe

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1. Introduction

In practice, accidents are hardly ever observed by the traffic safety researcher. Therefore the analysis of traffic safety problems is difficult. One often uses historic data, information about accidents that took place in the past. From this information a reconstruction is made in order to explain the occurrence of the accident. Such a reconstruction is only partly possible, because the historic data is incomplete and in many cases distorted.

An alternative approach starts with the study of traffic behaviour, especially the kind of behaviour that is supposed to be dangerous. The traffic conflict technique is the best known representative of this approach, but certainly not the only one. The question in the first approach is whether or not the information given is reliable, here the question is whether or not the situation is relevant. The problem with the first approach seems to bother researchers less than that of the last one. The attention to the conflict technique is primarily concerned with the problem of validation. The applicability of the conflict technique is often measured completely in terms of predictive validity and the applicants of this technique are often forced into the defense, to demonstrate how valid their technique is.

From a theoretical point of view, it is rather curious to see how little attention is given to the foundation of the implicit or explicit explanation of accidents, and to the diagnosis and recommendations that result from safety studies, accident studies included. Evaluation studies are in most cases restricted to before and after studies of accident numbers. These studies are aimed at the justification of the amount of money invested more than to learn from the past for future work.

This article discusses a broader scope for the foundation of safety research and deduces from that a more comprehensive approach to the evaluation of traffic conflict techniques.

The basic assumption is that the object of traffic safety research is not the accident, but the critical event in the traffic system that results in any accident. As a consequence, traffic safety research should start with careful and systematic observation of the dangerous situations in traffic, in order to detect the factors that cause the accident. In order to reduce the number of accidents, one has to control the traffic system. Therefore it is necessary to study the traffic system itself and not only the outcome of the situations that run out of control. As a result of this approach, the traffic conflict technique is looked upon as a method for the systematic observation of conflicting traffic behaviour. These observations lead to the detection of deficiencies in the traffic system that increase the accident potential.

Therefore, the evaluation of this method should be primarily concerned with its use for the confirmation of traffic safety theory and not with the prediction of accidents.

If it is possible to express the amount of danger of a traffic conflict
situation in a severity score, deduced from the factors that contribute to that danger, we are not only able to improve the prediction of accidents, but also to recommend or evaluate safety measures from the analysis of these combined factors.

2. The definition of conflicts

The definition of a conflict is not easy to give. There are various definitions in use. A first aim in defining a conflict, is to describe the so called "universe of discourse". The definition indicates the kind of traffic behaviour that one is interested in. In this case the connotation of the concept is more important than the denotation. If an operational definition is given, one tries to describe a decision rule by which it is possible to distinguish between situations that are or are not conflicts.

During the first international symposium in Oslo, the following definition of a conflict was approved:

"A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged."

This definition was not only meant as a general demarcation rule for conflicts but must also be regarded as an attempt to define conflicts operationally. Already in the investigations of Perkins and Harris, one of the first conflict studies that are carried out, an operational definition is used similar to the definition given in Oslo. Their definition is clear and easy to apply to car-car conflicts. In practice however, when the conflict technique is applied to different situations or to study various problems, various definitions are used. The reasons for this are:

- The research is related to a restricted safety problem, such as the safety of children crossing a street, the safety of pedestrians at intersections, the operational deficiencies of an intersection etc. Only those conflicts and behavioural aspects of these conflicts that are relevant for the investigation are taken into account.
- There are differences in observation methods. Subjective techniques make use of observations in the literal sense, using cues such as "sudden behaviour" or "avoiding behaviour", terms that need a judgement of the observer. Objective techniques use concepts such as "time-to-collision" (TTC, the time that remains until the accident will happen, if not evasive action takes place) or "post-encroachment-time (PET, the time that remains to react to an intruder entering the lane of a road-user). These concepts suppose the use of registration equipment instead of observers.
- Some techniques distinguish between severity-grades of conflicts. The severity-grade is mostly related to the probability of an accident to occur, but sometimes also to the consequences of such an accident (e.g. whether or not injuries are probable if an accident would happen). The severity dimension is in general hardly specified, and only described in terms of a more or less sudden reaction or a longer or shorter TTC-value. Some times other aspects are mentioned such as velocities, distances, type of conflict, participants in conflict etc. However, in most cases it is not clear how these aspects must be combined to establish the severity-scores. The Malmo study shows that trained observers use one common severity scale to score the severity of conflicts. Furthermore, this score is not based on a simple cue but on a combination of cues.
In the introduction we state that the conflict analysis has to be developed into a method for the systematic observation of risky interactive traffic behaviour. Before it can be used for this purpose it is necessary to know in which situations, what aspects of this interactive behaviour are risky. In this respect, the validity of a conflict-technique should be evaluated by its power to discriminate between conflict situations with a high accident potential and those with a low one, on the basis of situational characteristics. Therefore, not only those conflicts that result in accidents are important, but also those conflicts are controlled by the road-user. There is no fundamental difference between general traffic safety research and conflict analysis as far as the confirmation of the theory of risky traffic behaviour is concerned.

3. Implications for the validation of conflict techniques

As said before, a conflict method is not only useful if it predicts the number of accidents, but primarily if it convincingly indicates which types of interactive traffic behaviour are dangerous. Convincingly here means that the analysis of traffic behaviour is based on an established traffic safety theory. The value of a conflict analysis technique for traffic safety research is therefore not determined by the validity with regard to the prediction of accidents, but especially by the verification of the severity that is attached to a conflict situation on the basis of a traffic safety theory.

It is a misconception to think that this verification is exclusively of importance for the conflict technique. For each type of traffic safety research that leads from the observation of safety phenomena to a safety diagnosis and consequently to the recommendation of safety measures, it is necessary to evaluate the assumptions. In most cases only the end product of measures is evaluated by means of before-after studies of accidents.

In order to check the validity of the assumptions behind the implementation of safety measures with regard to the intermediate effects of these measures on traffic behaviour, it is necessary not only to evaluate the reduction in accidents, but also the changes in the process. This process-evaluation tells us not only whether a certain measure is effective or not, but also why this is the case. The severity grade of conflicts, in particular the change of conflict frequencies with regard to severity-grades can be used to check if assumptions about changes in the traffic system were correct. We will describe some relations between severity scores and the predictive validity.

We assume that different types of conflicts are distinguished, and that there is a particular type of accident $A_i$ related to that type of conflict $C_i$ with probability $p_i$. For a given location, during a given period, we observe conflict frequencies $f_i$ for the various types $C_i$. Figure 1 describes schematically the relation between the conflict observations and the predicted number of accidents. Assume that the conflict types are ordered with regard to the increase in $p$-values.
<table>
<thead>
<tr>
<th>Conflict type</th>
<th>Frequency</th>
<th>Probability of an particular accident</th>
<th>Expected number of particular accidents</th>
<th>Total number of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_1$</td>
<td>$f_1$</td>
<td>$p_1$</td>
<td>$A_1$</td>
<td></td>
</tr>
<tr>
<td>$C_2$</td>
<td>$f_2$</td>
<td>$p_2$</td>
<td>$A_2$</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>$C_n$</td>
<td>$f_n$</td>
<td>$p_n$</td>
<td>$A_n$</td>
<td></td>
</tr>
</tbody>
</table>

$$\begin{align*}
\sum_{i=1}^{n} f_i p_i &= A_i \\
\sum_{i=1}^{n} A_i &= A
\end{align*}$$

Model I: relation between conflicts and accidents.

With $p$ the severity of a conflict is given, with $f$ the number of conflicts.

The product of $f_i$ and $p_i$ results in the expected number of accidents $A_i$ for a given time-period. The sum of these expected accident numbers gives the expected number of accidents in total.

We will not go into detail with regard to the nature of the $C$’s, which is of course the most important issue in the application of conflict techniques, but take the operational definitions of the $C$’s for granted.

We will also neglect complicating factors such as the distinction in severity-grade of the accidents. In principle this problem can be solved by adding a weight-factor to the $A_i$’s before the final addition.

If we use the conflict analysis method to detect locations with a high accident potential, then we are primarily concerned with the prediction of $A$. If we use the method to analyse safety problems then the distribution of frequencies is of major concern.

If all types of interactive behaviour are scored and not just the dangerous ones, then the conflict method can be used to establish the distribution of particular types of desired and undesired behaviour. If the shape of the frequency distribution is unacceptable, safety measures that will change this distribution are needed.

In most cases however, no distinction with regard to the severity of conflicts is made. Interactive behaviour is binary classified into conflicts and non-conflicts. The limit between the two categories often differs in severity grade for different techniques. The binary classification results in a reduced model and accordingly leads to a loss of information:
Model II: binary classification into conflicts and non-conflicts.

A special case arises if $p_c = 0$ ("no accident without a conflict"). All information about $A$ is then stored in the total number of conflicts. This idea was behind the Oslo definition of a conflict. With this definition, exposure to accidents is an important factor in the prediction of accidents. Not the seriousness of conflicts, but the number of conflicts is of major concern in this case.

Now the first question with regard to validity is to what extent the reduction of model I to model II results in a loss of information and therefore in a decrease in validity. The second question is to what extent a binary classification such that $p_c = 0$ is sub-optimal.

With regard to the last question, safety measures will be proposed that result in riskless behaviour. It seems to be more realistic to aim at measures that change situations with a high degree of risk into situations with low risk, in other words to reduce the number of serious conflicts. A number of conflicts techniques only use serious conflicts to measure safety. The predictive validity of these methods is on the average higher than the methods that are based on the total number of conflicts as was to be expected. In this way the prediction of the number of accidents by means of the number of conflicts will become much more effective than the prediction by means of exposure (or traffic flows). The improvement of the severity rating will result in a better validity of conflict techniques.

Thus far, the classification of conflicts with regard to severity is taken for granted. This classification however, is the main issue for the improvement of the validity. The Malmo-study showed that the largest differences in scoring are given with the variation in detection and selection.

It was also shown that the selection problem decreased with the severity of conflicts.

The agreement between teams in the severity rating of a given conflict once it is detected, is much higher. Trained observers agree to a large extent on the severity score of conflicts. A combination of cues is used to establish this severity score. The scoring rule however, is not yet made explicite. Teams that concentrate on time-to-collision as the major cue also use other aspects of the conflict situation. A careful study of the situations that are scored is needed to make this subjective evaluation operational. However, the operationalisation of the common scoring rule is only the first step to be taken. We then know that observers agree on the face-validity of the cues that are relevant for the severity-concept and how they score it.

Whether this construct is also describing the real severity of the
conflict with regard to the occurrence of accidents or injury is still to be proven. The construct-validity of the technique is most essential. If we want to improve the technique, we have to check whether the aspects that are taken into account, indeed relate to real danger. Time-to-collision is important, because it measures the limit-conditions for control of the situation by the road-user involved. So far it fits in a general theoretic notion of safety control. However, ttc as such is not enough. It is shown that the ttc-curve is different for different situations. E.g. the fact that bicycles can be manoeuvred more easily to avoid a collision with another vehicle, is already demonstrated with the shape of the ttc-curve. It is however yet unknown how this shape of the ttc-curve relates to lack of safety. Furthermore, it is shown that the 1.5 seconds road-users seem to use as a margin for conflict avoidance, also appears to be used as a margin in other situations such as running of the road (time-to-line-crossing). A more fundamental study of this concept, e.g. with regard to car-following, gap-acceptance or overtaking may result in a better understanding of road-user behaviour in general and conflict-behaviour as a special case. Also the PET-measure needs attention, as indicated in the Trautenfels study. But time alone is not a sufficient base to score severity. The speeds at the moment of impact, differences in mass between participants, the level of protection of road-users etc. also play an important role. The definition of critical traffic behaviour by means of ttc, pet, conflict type and other factors makes the concept of severity operational and suitable for falsification. From this, a more constructive approach to the problem of validity is possible than if the process as such is ignored as a basis for evaluation and only the end-product, the number of accidents, is used as a target for predictive validation of traffic conflict techniques and the scoring rule is left implicit.
EVALUATION OF TCT:S, VALIDATION RESULTS


Presented at the seminar on "Traffic Conflicts and other intermediate measures in safety evaluation". Budapest, September 8-10, 1986.

As a complement to statistical comparisons of accident and conflict figures, I will present results representing a different approach. I have tried to compare the last part of the process leading to accidents and conflicts.

The definition of a serious conflict in our case is nowadays based on a relationship between Time to Accident (TA) and Conflicting speed (CS). TA is defined as the time that remains until an accident would have occurred if both road users involved had continued with unchanged speeds and directions; from the moment one of the road users starts taking evasive action.

Conflicting speed is the speed, just before TA is calculated, of the road user who takes evasive action. (If both road users take evasive action, the "least severe" action is defining the severity of the conflict. See later definition of severity).

Figure 1 presents graphically the Swedish definition of a serious conflict.

![Figure 1. The Swedish definition of a serious conflict.](image)
Severity is defined as the perpendicular distance from the border line.

The results I will present, represent examples from an on-going project.

Accidents and conflicts will be compared in three different ways:

1) The distribution of accidents and conflicts with regard to TA and CS.

2) The kind of evasive manoeuvre taken

3) For car-bicycle and car-pedestrian situations: Which one of the two road user types that were the relevant road user for the calculation of TA and CS.

Data on conflicts were obtained from an on-going project where statistical comparisons between accident and conflict numbers were made. Data on accidents were obtained through in-depth analysis of accident investigations carried out by the police.

1) Comparison of the distribution of accidents and conflicts with regard to TA and CS

In figures 2 to 7 the respective distributions are presented.

The six graphs primarily produce the following tentative conclusions:

The patterns are fairly similar in all six graphs. The main differences are:

- The accidents are located more to the left in the graphs, i.e. the TA-values are lower for accidents than for conflicts.

- Car-car accidents also have higher speed on average than car-car conflicts. Specifically very few accidents have speeds below 30 km/h while more than half of the conflicts have speeds below 30 km/h.

The main reason for this is probably that conflicts are supposed to reflect the likelihood of collisions and not injury accidents. It is obvious that the conflicting speeds at car-car accidents have to be above 30 km/h in most cases to produce injuries, while collisions also occur at lower speeds.

This is also confirmed by the car-bicycle and car-pedestrian graphs where there are quite a few unprotected road users that are injured at speeds below 30 km/h.
In a later stage of the analysis "uniform severity zones" were defined via lines parallel to the borderline between serious and non-serious conflicts. The distribution over severity of conflicts and accidents was calculated and compared. The analysis shows that in the "least severe zones" only conflicts were present, while for the "most severe zones" only accidents were present. In between there was an overlap. If number of accidents and conflicts per time unit was combined, the distribution indicated normality with accidents as a "logical ending" of the distribution in the "severe end". This clearly indicates that accidents and conflicts belong to the same distribution based on TA and CS. This in turn indicates that accidents and conflicts are similar in nature but may differ with regard to severity.

The number of accidents where the TA-value equals zero, i.e. where no evasive action was taken before the accident, varies from 6.5% in car-car accidents, to 29.5% in car-bicycle accidents and 24.0% in car-pedestrian accidents.

The likelihood of TA being equal to zero is very CS-dependent: At low conflicting speeds the likelihood is very high while at high speeds the likelihood is very low. The accidents where TA equals zero is a "logical part" of the TA-CS distributions shown earlier. Those accidents should therefore be interpreted as serious conflicts where there were not ample time to start an evasive action.

2) A comparison of the kind of evasive manoeuvre taken in accidents and conflicts

Table 8 presents a comparison based on the same sample of conflicts and accidents as before.
<table>
<thead>
<tr>
<th></th>
<th>Braking</th>
<th>Braking + Swerving</th>
<th>Swerving</th>
<th>Accelerating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Car - Car</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of conflicts</td>
<td>307</td>
<td>63</td>
<td>20</td>
<td>11</td>
<td>401</td>
</tr>
<tr>
<td>Number of accidents</td>
<td>77</td>
<td>16</td>
<td>11</td>
<td>2</td>
<td>106</td>
</tr>
<tr>
<td>Proport of conflicts (%)</td>
<td>77</td>
<td>16</td>
<td>5</td>
<td>3</td>
<td>101</td>
</tr>
<tr>
<td>Proport of accidents (%)</td>
<td>73</td>
<td>15</td>
<td>10</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td><strong>Car - Bicycle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of conflicts</td>
<td>142</td>
<td>41</td>
<td>14</td>
<td>0</td>
<td>197</td>
</tr>
<tr>
<td>Number of accidents</td>
<td>44</td>
<td>13</td>
<td>10</td>
<td>2</td>
<td>69</td>
</tr>
<tr>
<td>Proport of conflicts (%)</td>
<td>72</td>
<td>21</td>
<td>7</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Proport of accidents (%)</td>
<td>64</td>
<td>19</td>
<td>14</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td><strong>Car - Pedestrian</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of conflicts</td>
<td>220</td>
<td>15</td>
<td>7</td>
<td>6</td>
<td>248</td>
</tr>
<tr>
<td>Number of accidents</td>
<td>37</td>
<td>17</td>
<td>3</td>
<td>1</td>
<td>58</td>
</tr>
<tr>
<td>Proport of conflicts (%)</td>
<td>89</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>Proport of accidents (%)</td>
<td>64</td>
<td>29</td>
<td>5</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of conflicts</td>
<td>669</td>
<td>119</td>
<td>41</td>
<td>17</td>
<td>846</td>
</tr>
<tr>
<td>Number of accidents</td>
<td>158</td>
<td>46</td>
<td>24</td>
<td>5</td>
<td>233</td>
</tr>
<tr>
<td>Proport of conflicts (%)</td>
<td>79,1</td>
<td>14,1</td>
<td>4,8</td>
<td>2,0</td>
<td>100</td>
</tr>
<tr>
<td>Proport of accidents (%)</td>
<td>67,8</td>
<td>19,7</td>
<td>10,3</td>
<td>2,1</td>
<td>100</td>
</tr>
</tbody>
</table>
The number of conflicts and number of accidents for one type of evasive manoeuvre have been compared with the total number of conflicts and accidents. The following significant ($\chi^2$-test, 5% level) differences were found on the total data-set:

- "Braking + swerving" is more common among accidents
- "Swerving only" is also more common among accidents.

In the first case the found difference is only due to a difference in the car-pedestrian ratio. "Swerving only" seems to have very similar ratios for all three types of road users.

The two findings above indicate that swerving seems to be used to a larger extent at accidents than at conflicts. This may be due to the fact that the road users at accident-situations more often "try everything". Another reason that might be at hand is a bias in the accident analysis, namely that road users may try to indicate that they tried to avoid the accident at least by swerving. This kind of bias can not be checked.

The main conclusion however is that the agreement is great. In the vast majority of relations the similarity is quite convincing; only in 11% of the cases there had to be a change of the classification in order to achieve a complete agreement. On the whole one must therefore conclude that conflicts from this point of view are very relevant substitutes for accidents.

3) A comparison of relevant road users in car-bicycle and car-pedestrian conflicts and accidents

At each conflict in our sample Time to Accident and conflicting speed has been estimated for the road user that produces the least severe conflict. This road user is called the relevant road user. The same procedure is followed for the accident sample. For accidents with a TA-value of zero, i.e. there was no avoiding action prior to the collision, the relevant road user is defined as the one that hits the other at the collision. For car-bicycle and car-pedestrian conflicts the ratios of car drivers to bicyclists and car drivers to pedestrians can be calculated and compared with the corresponding ratios for accidents. Table 9 shows the result of such a comparison.
Table 9: Relevant road user in car-bicycle and car-pedestrian conflicts and accidents

<table>
<thead>
<tr>
<th>Road users involved</th>
<th>Relevant road user</th>
<th>Conflicts</th>
<th>Accidents</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car-Bicycle</td>
<td>Bicyclist</td>
<td>53</td>
<td>35</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(41%)</td>
<td>(28%)</td>
<td>(36%)</td>
</tr>
<tr>
<td>Car-driver</td>
<td></td>
<td>75</td>
<td>90</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(59%)</td>
<td>(72%)</td>
<td>(64%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>128</td>
<td>97</td>
<td>225</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100%)</td>
<td>(100%)</td>
<td>(100%)</td>
</tr>
<tr>
<td>Car-Pedestrian</td>
<td>Pedestrian</td>
<td>31</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(13%)</td>
<td>(9%)</td>
<td>(12%)</td>
</tr>
<tr>
<td>Car-Driver</td>
<td></td>
<td>206</td>
<td>72</td>
<td>278</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(87%)</td>
<td>(91%)</td>
<td>(88%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>237</td>
<td>79</td>
<td>316</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(100%)</td>
<td>(100%)</td>
<td>(100%)</td>
</tr>
</tbody>
</table>

x) Data are collected from figures 2-7

The number of relevant bicyclists compared to the total number of involved road users in car-bicycle situations is significantly higher ($X^2$-test, 5% level) in conflicts than in accidents. This is not the case with pedestrians.

We can see from table 9, that pedestrians are much less often defined as the relevant road user than bicyclists are. This difference is significant both for conflicts (significance level 0.5%) and for accidents (sign. level 5%).

To conclude and rephrase:

- In both conflicts and accidents the number of pedestrians was lower for accidents. This is probably due to the fact that conflicts involving bicyclists and pedestrians as relevant road users are less severe than the other conflicts, i.e. "conflicting speed" is lower and "Time to Accident" is higher on average for the first group. The number of conflicts per accident is therefore smaller for conflicts where the pedestrian or the bicyclist is the relevant road user. It is therefore to be expected that the proportion of relevant bicyclists and pedestrians is higher for conflicts.

On the whole this comparison produces similarities that support the idea that conflicts can work as substitutes for accidents.
INTRODUCTION

How can you tell if a Traffic Conflicts Technique (TCT) is valid? Some will regard the technique as valid if it proves successful in predicting accidents. Others will judge validity by the significance or magnitude of the correlation between conflicts and accidents. It is, therefore, important to start out with defining what validity ought to mean in this context.

In this paper I will talk about the issue of validity only when the TCT is used to estimate the safety of a location, e.g., an intersection. Safety here means the expected number of accidents (by severity) occurring at the location per unit of time. When the validity of the TCT is questioned, one is in fact asking whether the estimate of this expected number is valid. It is important to remember that the performance of the TCT should never be judged by its success in predicting actual number of accidents. That would be like predicting the roll of a die.

If one compares different methods for the estimation of safety, the most valid (best one) is the one that produces unbiased estimates with the smallest variance. In other words, a method is not valid or invalid. Validity is a matter of degree, and is preferably measured by the variance of the estimate. Whether a certain estimate is considered satisfactory or not, depends on the variance of the estimates obtainable by other methods and on the cost of estimation. Thus, to examine the validity of the TCT, it is necessary to explore the accuracy of the safety estimates which it produces.

USE OF TCT

At a specific intersection the number of accidents is often so low, that one will have to collect several years of accident data in order to ascertain the accident frequency with any degree of accuracy. This is often true even if
\[ E(X_k) = C_k \Pi_k \]  
\[ \text{If } X_k \text{ obeys the Poisson probability law} \]
\[ E(X_k^2) = C_k \Pi_k + C_k^2 \Pi_k^2 \]  
\[ \text{From equations 2 and 3} \]
\[ \frac{\sum_1^K \Pi_k}{K} = \frac{\sum_1^K E(X_k')/C_k}{K} \]  
and\[ \frac{\sum_1^K \Pi_k^2}{K} = \frac{\sum_1^K \frac{E(X_k^2) - E(X_k)}{C_k^2}}{K} \]
\[ \text{As } K \to \infty \text{ the left side of equations 4 and 5 converges to } E(\Pi) \text{ and } E(\Pi^2). \]  
\[ \text{Accordingly, the right hand side of equations 4 and 5 will be used to estimate } E(\Pi) \text{ and } E(\Pi^2). \]
\[ \text{To estimate } C_k^2, \text{ note that} \]
\[ E(Y_k) = C_k (M_k/N_k) \]
\[ \text{By the reasoning used to derive equation 5 we find} \]
\[ C_k^2 = (E(Y_k^2) - E(Y_k)) / (M_k/N_k)^2 \]
\[ \text{Using now the realizations } X_k \text{ and } Y_k \text{ to replace expected values we write:} \]
\[ \hat{E}(\Pi) = \frac{\sum_1^K X_k/(Y_k N_k / M_k)}{K} , \]
\[ \hat{E}(\Pi^2) = \frac{\sum_1^K \frac{X_k^2 - X_k}{(Y_k^2 - Y_k)(N_k / M_k)^2}}{K} , \]
\[ \text{VAR}(\Pi) = \hat{E}(\Pi^2) - (\hat{E}(\Pi))^2 \]

b) The Method of Maximum Likelihood

Each system of a population is associated with a specific value of \( \Pi \). Taken together, the values of \( \Pi \) in a population form a certain probability distribution function (PDF) which has a specific variance. To make inferences about this variance by the method of moments, it was not necessary to make any assumptions about the functional form which fits the PDF of \( \Pi \). In contrast, the estimation method to be described below begins by assuming that the distribution of \( \Pi \) over the population of systems can be described by the Gamma probability density function below:
\[ f(n) = n^{r-1}e^{-nr}/\Gamma(r) \quad \text{for } r > 0, \ 0 \text{ otherwise.} \] (11)

The parameters \( n \) and \( r \) are linked to the mean and variance by \( E(n) = \frac{r}{n} \) and \( \text{VAR}(n) = \frac{r}{n^2} \).

When the reported number of accidents obeys the Poisson probability law,

\[
P(X_k | C_k) = \int_0^\infty P(X_k | C_k, \Pi) d\Pi =
\]

\[
\left(\frac{r}{r+C_k \text{E}(n)}\right)^r \frac{\Gamma(r+X_k)}{\Gamma(r)} \frac{C_k \text{E}(n)}{(r+C_k \text{E}(n))^{X_k}}
\]

The probability of observing realizations \( X_1, X_2, \ldots, X_K \) when \( C_1, C_2, \ldots, C_K \) are known is the product of expressions as in equation 12. We wish \( \text{E}(\Pi) \) to be estimated by the ratio of sample means \( \overline{X}/\overline{C} \). This makes \( n = r\overline{X}/\overline{C} \).

Therefore, we can write the likelihood function \( L(r) \) for \( r \) as:

\[
L(r) = \Pi P(X_k | C_k) =
\]

\[
= (\text{constant}) \left(\frac{r}{r+C_k \overline{X}/\overline{C}}\right)^r \frac{\Gamma(r+X_k)}{\Gamma(r)} (r+C_k \overline{X}/\overline{C})^{-X_k}
\] (13)

The task now is to find \( r \) for which \( L(r) \) is largest. This is easy to do numerically.

**PERFORMANCE OF THE TWO ESTIMATORS**

To show how these two methods perform, simulations were carried out. A PDF of \( \Pi \) was specified. At random, \( K \) values of \( \Pi \) were chosen. Each intersection was assigned an expected number of accidents per year. The durations of the conflict studies and accident recordings were chosen. Random realizations of \( X_k \) and \( Y_k \) for \( k = 1, 2, \ldots, K \) were generated. From these, estimates of \( \text{VAR}(\Pi) \) were calculated by both the methods. Besides this, \( \Pi_k \) was calculated for each intersection as \( (Y_k/X_k) \cdot (M_k/N_k) \). Then an estimate of \( \text{VAR}(\Pi) \) was calculated "directly" from these \( \Pi_k \) as a third method. The simulations can be described by the following diagram.
Simulation principle

Results from simulations which assumed that the PDF of $\Pi$ was of gamma type and that accidents and conflict numbers were realizations of Poisson variables show that both the methods are satisfying. The sample mean for 500 estimates of $\text{VAR}(\Pi)$ was off less than 5% from the input for each method. The direct method, however, does not give unbiased results. This method gave an overestimation of more than 100 percent. When choosing between the method of moments and the maximum likelihood, the latter seems to give estimates of $\text{VAR}(\Pi)$ more concentrated around the mean, and should therefore be preferred.

REFERENCES


Figure 2. Time to accident and conflicting speed in car-car accidents
108 injury accidents, Malmö 1977-1980

Non filled = Slight injury accident
Half filled = Severe injury accident
Filled = Fatal accident

○ ; Car-car
△ ; Car-motorcycle. Car takes evasive action
▽ ; Car-motorcycle. Motorcycle takes evasive action
Figure 3. Time to accident and conflicting speed in car-car conflicts
396 serious conflicts recorded in Malmö, 1982-1983

- □ = Left-turning vehicles versus on-coming
- ● = Perpendicular
- ★ = Rear-end, merging
Figure 4 Time to accident and conflicting speed in car-bicycle accidents
125 injury accidents, Malmö 1978-1980

Non filled = Slight injury accident
Half filled = Severe injury accident
Filled = Fatal accident
○ ; Car-bicycle. Car takes evasive action (73 acc)
□ ; Car-bicycle. Bicycle takes evasive action (24 acc)
△ ; Motorcycle-bicycle. Motorcycle takes evasive action (17 acc)
▽ ; Motorcycle-bicycle. Bicycle takes evasive action (11 acc)
Figure 5  Time to accident and conflicting speed in car-bicycle conflicts
128 serious conflicts recorded in Malmö, 1982-83

* Car is taking evasive action (75 confl)
* Bicycle is taking evasive action (53 confl)
Figure 6  Time to accident and conflicting speed in car-pedestrian accidents
79 injury accidents, Malmö 1977-80

CS (Km/h)

TA (Sec)

Non filled = Slight injury accident
Half filled = Severe injury accident
Filled = Fatal accident

○ ; Vehicle takes evasive action (66 acc)
□ ; Pedestrian takes evasive action (7 acc)
△ ; Motorcycle - Pedestrian. Motorcycle takes evasive action (6 acc)
Figure 7 Time to accident and conflicting speed in car-pedestrian conflicts

CS 237 serious conflicts recorded in Malmö, 1982-83

- ; Vehicle takes evasive action (206 confl)
- ; Pedestrian takes evasive action (31 confl)
VI. INTERNATIONAL CALIBRATION OF TRAFFIC CONFLICT TECHNIQUE

Almqvist, Sverker  International calibration of Conflict Techniques. ICTCI-studies in Malmö and Treutenfels

Risser, Ralf  The "Treutenfels study"

Oppe, Siem  The international calibration of conflicts: A summary of the results
International Workshop On
Traffic Conflicts and Other Intermediate
Measures In Safety Evaluation

Budapest, September 8-10, 1986

International Calibration of Conflict Techniques
ICTCT-Studies in Malmö and Trautenfels

Design of the Malmö-Study

by

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Introduction

Within the group of traffic safety researchers working with TCT, there was growing interest of comparing the different countries techniques and applications. The first idea of a joint calibration study was born.

The aim of such a study were:

1) to compare the different techniques with regard to similarities and differences and how different teams record the same conflict-situations, over-all compared with objective measures.

2) let every participating team present a safety diagnose for the studied sites.

After a time of preparational discussions the swedish town Malmö was selected for the purpose where the calibration study could take part.

At a planning meeting in Sweden several possible intersections with different characteristics as, type of regulation, location in the city, geometry, recording sites, etc., was inspected.

The time for the fieldwork was limited to two weeks. The optimal compromise with regard to available time and need of enough data was to limit the number of locations. Three intersections were then selected for the study. Each intersection then should be studied for three days. The selected intersections had a little various conditions in a positive way, but in common they had a considerable mix of roadusers and were fairly busy, at least for swedish circumstances.

Intersection n:o 1 in the study
Intersection n:o 2.

Intersection n:o 3, signalised
Participating in the study.

For conflict calibration study following teams took part:

Austria: Kuratorium für Verkehrssicherheit (KFV), Vienna
Canada: Transport Canada, Ottawa
Finland: Technical Research Centre (VTT), Espoo
France: Organisme National de Sécurité Routière, (ONSE), Arcueil
Germany: Technical University, Braunschweig
Great Britain: Transport and Road Research Laboratory (TRRL), Crowthorne
Netherlands: Institute for Perception (IZF-TNO), Soesterberg
Sweden: University of Lund, Lund
USA: Midwest Research Institute, Kansas City

At the same time an accident analysis and behavioural study were carried out by the Danish Council of Road Safety Research.

The objective data were collected by using a video-based technique by the Institute for Perception (IZF-TNO), Soesterberg, the Netherlands.

Besides above the mentioned teams, representatives from the Road Safety Centre at Techunion, Haifa, Israel, the Department of Civil Engineering, University of Leuven, Belgium, the local road office of Malmö and the Swedish National Road Administration, followed the study.

The participating countries team used their own techniques. In a couple of cases, France and Sweden also took the opportunity to test different scales of the technique.

For the calibration study some other modifications were caused by the following reasons:

- the number of observers had to be limited
- shorter observation period in total
- various intersection geometry

All eight teams performed the observations simultaneously through the whole study. From the start there was an uncertainty about what would happen when 15-20 observers were exposed at the same location. The fears were needless - when the experienced observers started working, they merged into the surroundings and did not wake any attention or were disturbed by each other.

Three days of observation at each intersection, appr. 6 1/2 hour of observation every day, spread over the day, but peak hours were covered two or three times, in order to obtain as many conflicts as possible. For the same reason only weekdays were used for observation.
Recording and labelling

The number of observers varied between one and three of each team.

All countries used their own observers except for Canada, which trained three Swedish observers in advance of the study.

Before every new location, the observation area was strictly defined. Restriction lines were often the zebras, and/or what was possible to cover with the video recordings.

The observers were free to choose their observer-location and what they were familiar with.

The common position of the two observers were diagonally, and 5-30 m upstream in the approaches along, the video-recordings were made.

A common data sheet was used of all teams. To identify the different situations the observers were instructed to fill in the exact time when the conflict occurs. All observers were equipped with digital watches that were synchronized. Other data was collected as well, about the conflict the road users were involved in, severity, colour of cars, age, sex, etc.

On the data sheet there was also space left over for each team to add information for internal use.

After each day of observation one set of data from each team was delivered to the labelling team.

FIGURE: (Next side) Example of the common data-sheet used.
I

Sketch of conflict:

Please note: Trajectories, number or reference of road-users, particular movements as breaking, stopping, skidding, falling etcetera.

Additional data/Comments (to be defined by each team)
The labelling team used video-recordings to identify the recorded conflicts. Every conflict-situation was given a unique number and a list was also made up with conflict number, the exact time of the conflict, conflict type manoeuvres and the number of teams scoring the situation as a conflict.

Objective data were collected by the team from IZF-TNO, the Netherlands. The major purpose of the quantitative analysis was to produce an objective description of conflict situations for the comparison of severity ratings between the teams.

A method, based on recordings from video, followed by a quantitative analysis, was used. (See van der Horst 1982, 1983)

For the whole study 48 hours of video recordings were made. Three different video systems were in practice. U-matic was used for the objective analysis, a time-lapse video-recorder was running besides and also during the intervals between observation periods, and finally a VHS-recorder was in function for the next days labelling session.

LITERATURE

The Malmö Study, A calibration of traffic conflict techniques. 1984. Institute for Road Safety Research, SWOV. Leidschendam. The Netherlands
The Trautenfels Study was a traffic study in the framework of a project dealing with the traffic on Austrian transit routes. This project was financed by the Bundesanstalt für Straßenwesen in Germany and by the Ministry of Science in Austria and the Austrian Road Safety Board.

Main Aims of the Study

- Description of typical behavior of car drivers belonging to different nationalities in order to get hints how to influence the behavior of those groups (the conflict registration was done out of the car following the subject's cars).
- Diagnosis of selected dangerous spots in the Austrian traffic road network.
- Modification of those spots based on the conflict registrations, and after studies in order to analyze the changes in traffic behavior.

Behavior Observations

were done out of a car following the subjects' cars; the probability of any selected subject leaving the main road was very low, so it was quite easy to get samples big enough to provide for data which can be compared to each other. Observations were done without the knowledge of the observed subjects, thus half an hour was sufficient to collect all the data necessary. However, on federal roads, where the observations were done, very few conflicts happened during half-hour rides, so we could not use conflict numbers as criteria for the description of typical behavior of different nationalities.

Diagnosis of Dangerous Spots, Counter Measures and After-Studies, however, were based on on-the-spot-registration of traffic-conflicts.

Interrate Correlation

As known, up to now no satisfying correlations between traffic-conflicts and accident data could be found in order to proof that traffic-conflicts and accident data mediate the same problems. However, there are very important pre-conditions for validation studies in this respect:
Critical events - especially traffic conflicts - have to be registered with sufficient reliability.

- Different observers looking at the same events should register the same things.
- The consequences resulting from conflict observations of different teams should be comparable (of course, considering typical national differences in coping with traffic problems).

Aims of International Cooperation

Within the framework of the project we aimed at two things:

1. Comparison of the processes leading to countermeasures, and evaluation of countermeasures.

   Austrian experts had done diagnosis on 12 spots in the Austrian transit-route-network, they had suggested counter-measures on selected six of those spots and analysed the situation after the setting of the countermeasures. Those steps should be compared with similar steps of none-Austrian teams; the comparison should be done vicariously on two of the six modified spots.

2. Comparison of diagnosis: Diagnosis itself should be analyzed, vicariously comparing the Austrian diagnosis of one spot to the results of several other non-Austrian teams. This comparison was done after the setting of countermeasures, the non-Austrian teams not being informed about the nature of the countermeasures.

Calibration

For a quantitative comparison of a number of different teams of conflict observers it is necessary that data themselves be quantitatively comparable. This pre-condition is not in itself provided for when looking at results of different countries. In order to make data comparable, we have to calibrate them. The most important calibration study up to now was the one done in Malmö. Cooperation in Trautenfels done to provide a kind of an internal validation for diagnosis-
data was a good opportunity to collect more data for calibration-calculations, and, what is more, on a type of intersection which up to now was analyzed quite rarely.

Working Plan

In pre-tests resp. in the before-study - the international work was done parallely to the after-study - the Austrian team had counted between 1 and 5 conflicts per hour on the junction of the national roads (3 308 / B 345 / B 146 / B 75) in Trautenfels. For methodological work on calibration, though, at least 50 conflicts observed by at least 2 teams were needed. In order to get that number, 30 hours of observation were planned, almost half of them during week-end traffic.

The teams taking part - Finland, France, Israel, the Netherlands, Sweden, the United States of America and Austria - should take their place at the junction as they were used to, trying, though not to catch the traffic-participant's eye too much. The minimum number of observers necessary to cover the cross-road should be present at any time of the observation period. All the teams agreed on the inner junction area as being the actual observation area (see figure 1). However, observers were allowed to cover a larger part of the cross-road than the actual observation area, according to their usual way of looking at similar road-sections. The only pre-condition was, that every team should cover all of the actual observation area.

Resulting Data

1. 166 conflicts were gathered, 81 of them were observed by at least two teams. Data were passed on to the SWOV in the Netherlands for calculation.

In the framework of the Trautenfels calibration study we tried to get answers to some special questions connected to calibration problems:

- If the situation judged as a conflict by other teams was not registered as a conflict by one special team, that team should try to specify what the reason was for missing the conflict using the video recordings of the collected traffic-conflicts (e.g.
Figure 11: Junction of the national roads B 308 / B 146 / B 145 / B 308
conflict outside observation area; at the border of observation area; not seen from the observer's post; view temporarily obstructed by a truck; observer distracted, etc.

If the situation was considered not a conflict what were the reasons, (e.g. no collision course; no evasive action; evasive action not an emergency action, but a preventive one; no surprise, communication among road-users, no violation of right-of-way, etc.; time to accident too large, minimum time to collision too large, relation speed-distance mediates no danger; relation speed TTC or TTA mediates no danger; mistake of judgement)?

2. Also using video recordings the teams should try to reconstruct their decision on the severity of the conflict (speed; speed related to TTC or TTA; distance between road-users versus speed; strength of the evasive action; elements of surprise, e.g. visibility, violation of right-of-way, etc.; probability of collision; outcome: probability of injury, e.g. type of road-users involved, angle of collision, etc.).

3. If a traffic conflict was not registered by one special team because it was missed this team should try to relocate that event on the severity-scale using the video-tape, if possible.

Dealing with these questions we expected some information about the criteria influencing the reliability of conflict registration. Another aim was to make the processes of decision concerning severity of traffic conflicts clearer.

More information about data processing and calibration results, see report of Siem Opps and Richard van der Horst.
THE INTERNATIONAL CALIBRATION OF CONFLICTS: A SUMMARY OF THE RESULTS

S. Oppe

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1. INTRODUCTION

In the summer of 1983 an international study organised by ICTCT took place in Malmö in Sweden. Conflict-teams from eight countries joined the study together with experts from four other countries. This was the first time to our knowledge that an international study on such a scale has been carried out.

The main purpose of the study was to compare results of different conflict-teams and find a common basis for detailed discussion on the use of conflict techniques.

In September 1985 a second international study of ICTCT took place in Trautenfels in Austria. This study was made on a smaller scale and resulted in additional information on the use of conflict techniques in rural areas. A full description of the first study can be found in "The Malmö-study, a calibration of traffic conflict techniques, SWOV, Leidschendam, 1984. A report on the Trautenfels-study is in preparation. This paper gives a short description of the main results. It is primarily based on the Malmö report, but results of the Trautenfels study as far as available will be incorporated. Section 2 starts with a brief general description, primarily concerned with a discussion on the selection of conflicts. Section 3 discusses the severity scoring which was the main issue of the Calibration Study. Finally section 4 describes the relation between severity scores and objective characteristics of the conflict situation.

2. GENERAL DESCRIPTION OF RESULTS

The total number of conflicts that have been scored in Malmö by at least one team is 973. 116 conflicts were scored by at least four teams out of eight. The Trautenfels study resulted in 166 conflicts. 46 conflicts were scored by at least three teams out of six. From this it follows that there must be substantive differences in scoring between teams. The two possible sources for the differences are detection and selection. These sources may be related. Here we describe systematic differences with regard to teams, conflict types or days of observation.
Table 1. Number of conflicts according to day of observation and intersection in the Malmö study.

From table 1 it follows that the number of conflicts decreases with time of observation. This surely is a result of selection. If an observer is "adapted" to the location he has to evaluate, the number of scored conflicts decreases.

From table 2 it follows that there also are large differences between teams.

Table 2. Different types of conflicts for the eight teams in the Malmö Study.

England and Canada scored the most conflicts, Sweden and France the least. For the main types of conflicts, those involving one or more cars, a large interaction is found between teams and conflict type ($X^2 = 50.22$, df=21). Canada scored proportionally more conflicts of types 1 and 3 and less of type 2. England also scored more type 1 conflicts than the other countries. Austria, Germany and the USA scored higher proportions of type 2, but not significantly so.

From table 3 it follows that there are also considerable differences between countries, with regard to the type of manoeuvre made by the road users.
Table 3. Conflicts from the Malmö Study for each country, divided according to type of manoeuvre.

Canada had less type 1 (rear-end) and type 2 (weave or merge) conflicts, but more of types 3 (right angle) and 5 (left turn). Also type 6 (right angle with turn) and especially type 9 (pedestrians) were low. For England, manoeuvres 3 and 6 were recorded more frequently, and 5 and 9 less frequently. There were also many other differences between the teams, primarily concerning the right angle, the left turn, the right angle with turn, and the pedestrian conflicts.

In conclusion we can say that selection of conflict situations depends to a large extent on observation time, type of conflict and manoeuvre type and on the number of conflicts in general.

3. SEVERITY SCORING

The major aim of the study was a detailed comparison of the severity scoring of each team. For this purpose the scores of all conflicts are analysed as well as the subset of conflicts that are scored by more than three teams. The data are analysed with PRINCALS, a computer-programme for homogeneity analysis of classified data. The programme results in a principal components analysis together with an optimal scaling of the conflicts and the scoring categories of the teams. For a description of this technique refer to Gifi (1980).

In the analysis of all Malmö conflicts as well as in the analysis of selected conflicts, only one common dimension is found. The same is true for the Trautenfels data. Table 4 shows that all component loadings are between .50 and .84.
-4-

<table>
<thead>
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<th>COMPONENT LOADINGS</th>
<th>Trautenfels</th>
</tr>
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Table 4. Component loadings of PRINCALS-analysis for Malmö/Trautenfels data.

This study strongly suggests the use of a one common severity dimension. This means that, although the differences in detection and selection as mentioned before are substantial, teams agree on the severity of a conflict once it is scored. This is confirmed by the values of table 5a, b and c representing the category-scores in three different analyses. From these scores it follows that apart from some minor exceptions the category-scores increase with the category-number. This means for all teams that on the average conflicts that belong to a higher category are indeed more serious than conflicts of lower categories or conflicts that are not scored.

<table>
<thead>
<tr>
<th>TEAMS</th>
<th>CATEGORIES</th>
<th>1</th>
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Table 5a. Category scores for the set of all conflicts from a one-dimensional PRINCALS analysis of the Malmö data.
Table 5b. Category scores for the set of selected conflicts from a one-dimensional PRINCALS analysis of the Malmö data.

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Table 5c. Category scores of the set of all conflicts from a one-dimensional PRINCALS analysis of the Trautenfels data.

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</table>

A comparison is made between the severity scores of the conflicts in the selected set from the analysis of all conflicts and from the analysis of the set itself. This comparison shows that the vast majority of the selected conflicts have a severity score in the analysis of all conflicts that is above the average value as was expected. Therefore, the selected conflicts appear to be also the more serious conflicts. Furthermore, it is found that within the set of selected conflicts, the severity-scores from both analyses correlate highly (r=.89). This suggests that the severity-scaling is stable over the complete severity range and that the criteria for severity do not shift with the location on the scale.

Finally it can be mentioned that a severity-scale results from the PRINCALS Analysis. In figure 1 all conflicts are located on this scale as well as all categories of the teams. From this ordering comparisons are possible between categories from different teams, as was one of the aims of the calibration study. Furthermore, comparisons between conflicts with regard to subjective severity scores are possible. A video-tape has been constructed for the analysis of the severity-scores of these conflicts. Objective characteristics of the selected conflicts...
are also available to support this kind of analysis. The next section gives some results from such an analysis.

4. THE RELATION BETWEEN SEVERITY AND OBJECTIVE CHARACTERISTICS

In order to make a comparison between the subjective scores and objective characteristics of the conflict situation, the following objective characteristics are established:
- type of conflict
- manoeuvre type
- minimum time-to-collision (ttc)
- manoeuvre-time (pet)
- minimal distance between road users (mdis)
- distance between road users at minimal ttc (dttc)
- speed of road user 1 and 2 ($v_1$ and $v_2$)
- deceleration of road user 1 and 2 ($A_1$ and $A_2$)

The institute for Perception (IZF-TNO), Soesterberg developed a semi-automatic procedure to score the measures from video-tape. It is based on the analysis of the successive pictures of the video-tape. On fixed time intervals precise measurements are made of the exact location of the road users of the video-picture. This is done, using cross hairs to fix the x- and y-coordinates on the video-picture. By projection of the video-locations onto the real intersection, distances, speeds, decelerations, ttc's and pets are calculated. A computer was programmed to do this automatically. The cross hairs were manually controlled.

Because of financial reasons, only the set of selected Malmö conflicts have been analysed.

122 of the original 169 Trautenfels conflicts could be analysed by means of the IZF-TNO procedure. The main reason for the reduction in number is the lay-out of the intersection. Not all parts of the intersection are covered completely by the video-picture. Furthermore it was not possible to analyse conflicts at some locations of the intersection in the picture.

The first step in the analysis was a comparison between the severity-scores that resulted from the PRINCALS-analysis and the ttc-values. 14 conflicts out of the original 116 Malmö-conflicts were excluded because there was no collision course and therefore no ttc. (The number of non-pet-situations was 43 out of 116).

From the 122 Trautenfels-conflicts, 27 conflicts had no ttc-value, while 72 conflicts had no pet-value.

Figure 2 gives the plot of the severity scores on the absciss vs. the minimum ttc-scores on the ordinate for the data of the Malmö-study. This plot shows that all conflicts are located in the lower left part of the coordinate system. The fact that there are no severe conflicts with a high ttc-value but there are non-severe conflicts with a low ttc-value suggests that ttc is a necessary but not a sufficient condition for the severity as scored by the observers. Other factors are also important, but do not seem to compensate the ttc-effect. An analysis of the Trautenfels Study confirmed this
result. Also here we found no conflicts above the diagonal but only in the lower left area of the plot.

The second step consisted of a number of CANALS-analyses. CANALS is a computer programme for canonical correlation analysis of categorised data. Like PRINCALS, CANALS also combines a linear analysis with a scaling of the variables that are used. It results in a scaling of all variables such that the canonical correlation between two sets of variables is maximum. For details refer again to Gifi (1980).

In a step-wise multiple regression-type of analysis with CANALS, the relation between the PRINCALS severity scores and the objective characteristics was investigated with and without TTC and PET. Table 6 shows that PET had almost no contribution to the relation and that TTC is the most important variable. Furthermore, that the weights for the other variables do not change much if TTC is added, but the overall fit improves. This supports the earlier finding that the contribution of TTC to the solution is unique.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>MALMÖ WITHOUT TTC, PET</th>
<th>MALMÖ TTC, PET INCLUDED</th>
<th>TRAUTENFELS TTC, PET INCLUDED</th>
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<td>DECELERATION 2</td>
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<td>-.27</td>
<td>.27</td>
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<td>CAN. COR.</td>
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<td>.99</td>
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</table>

Table 6. Correlation of variables with canonical axis of second set of CANALS analysis of subjective measures vs. PRINCALS scores, without TTC and PET (col.1), and TTC and PET included (col.2).

Table 7 shows the canonical correlation coefficients for all combinations of the three most important predictors of the severity. It shows that TTC is as good a predictor as conflict type and minimum distance together; that conflict-type adds most to this solution and minimum distance hardly improves the solution of TTC and conflict type. These results suggest that the restriction of a TTC-analysis to a particular conflict-type may result in a better solution than applied to the total set of conflicts.
Preliminary results from the CANALS-analysis of the 122 Trautenfels conflicts show that if the situations without PET or TTC-scores are counted as missing values for these variables PET is most important, Speed and Deceleration are more important, TTC less and conflict type not important any more. The last result is mainly due to the lack of pedestrian and bicycle conflicts. The increased effect of speed and acceleration may be due to the fact that the intersection is not urban but rural. If we correlate the PET-values with the severity scores from the analysis of the 122 Trautenfels conflicts only for those 50 conflicts that have a PET-value, ignoring the others, then we find the highest correlation in the complete set (r = -.78). This suggests that if the PET-value can be scored, then it is a very important factor for this kind of situation.

For TTC the value drops in this case further to r = -.25. The data are given in Table 6. Further analysis is necessary to interprete these preliminary results.

A number of CANALS-analyses are carried out in order to investigate differences between teams with regard to objective aspects of the conflict situations. Figure 3 shows the results from one of these analyses. In this analysis the classifications of the teams are compared to TTC and PET. As in ordinary canonical correlation analysis, arrows correspond to the projection of a vector in a multidimensional space (that represents the set of scores of a team) onto the plane that is spanned by the vectors that represent TTC and PET. Long arrows correspond to high correlations, small angles between arrows correspond to high correlations between projections.

We conclude here that the relation between the scores of Canada and the PET values is lower than was expected. High PET values tend to be associated with low severity scores and not-scored conflicts, but the scaling is irregular. France 1 seems to correlate highly with PET and with TTC as well.

Austria and England correlate primarily with PET and not with TTC. Austria, however, has a positive correlation with PET, while for England we find a negative correlation between the severity scaling and the PET value. The Finnish and USA teams correlate highest with TTC, but the
Swedish scores correlate less with TTC than was expected. In general we can say that for each team the relation to the common severity score of the PRINCALS analysis is much stronger than the relation to a combination of the minimal TTC and PET values. If there is a relation, then the scaling is not clear in many cases. Furthermore, for no team was the correlation with the best combination higher than .41, and no component loading on the PRINCALS dimension was lower than .50.

In a final analysis of the Malmö-data with a new developed computer programme OVERALS the teamscores are directly related to the objective characteristics. This analysis is not reported in the Malmö report. Refer to Verdegaal 1986 for an extensive description of the technique and results. OVERALS is a generalisation of canonical correlation analysis. It rescales categorical variables in two or more sets such that group representations are as homogeneous as possible. In this case there are eight groups, consisting of just one variable (the teamscores for each team) and one group consisting of all objective variables. The difference with canonical analysis is, that not the best representative team but the best average of the teams will be related to the objective data.

Table 8 shows the component loadings of the variables.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>COMPONENT LOAD.</th>
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<tbody>
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<td>TTC</td>
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</tr>
<tr>
<td>PET</td>
<td>-.41</td>
</tr>
</tbody>
</table>

Table 8. Component loadings of OVERALS-analysis for selected set of Malmö conflicts.

It follows that the PRINCALS-loadings from table 4 are similar to the OVERALS loadings for the teams. Also the CANALS-loadings for the objective characteristics are very similar to the OVERALS-loadings. The only significant difference is the high PET-value.
This result suggests that the dimension that is common to the team-scores as such is also the dimension that describes the relation of the team-scores and the objective data best. Whether this dimension also gives the best indication for danger needs to be investigated further by means of validation studies. The results of the Malmö-study are at least promising.

REFERENCES


Figure 1. Severity scale, with conflicts at the right hand side and categories at the left hand side, from PRINCALS on the set of selected conflicts.
Figure 2. Plot of the TTC values against the object scores from the PRINCALS analysis of the set of selected conflicts.
Figure 3. CANALS plot of the projections of the optimally scaled teams on the plane through TTC and PET, from the analysis of selected conflicts.