

Marian TRACZ, Andrzej TARKO, Stanislaw GACA
Cracow University of Technology

INTERSECTION SAFETY RESEARCH IN CRACOW UNIVERSITY OF TECHNOLOGY

1. Trends in traffic safety in Poland

Research activity in the area of interactions of road users at intersections and pedestrian crossings conducted in Cracow University of Technology are presented in this paper. These research projects are related to trends in traffic safety in Poland.

In 1989 in Poland there were 46338 road traffic accidents with 6724 people killed and 53659 injured [1]. There were also other 98768 road collisions recorded by police - without casualties and with vehicle damage only. The number of accidents and numbers of people killed and injured in road traffic accidents reached very high level in 1981. These numbers however begun to decline since 1982 and have continued to decline by 1988 (Table 1). There was especially a remarkable decrease of 23% in number of deaths. These figures are associated with improvements of road safety facilities and also with petrol coupon system.

Table 1. Changes in the number of traffic accidents and casualties

Year	Number of accidents	Index	Injured	Index	Killed	Index	Collision/damage only/	Vehicles
1980	40373	100.0	46245	100.0	6002	100	87979	5495935
1981	43755	105.4	51365	111.1	6107	101.7	85201	5853014
1982	38832	96.2	45696	97.8	5535	92.2	66111	5995702
1983	40454	100.2	47463	102.6	5561	82.6	62993	6416957
1984	35768	89.6	41325	89.4	4980	82.9	76300	6849648
1985	36100	90.2	42290	91.4	4608	78.1	78578	7088876
1986	37133	92.2	43150	93.3	4667	77.8	84668	7473247
1987	36433	90.2	42272	91.4	4625	77.0	78573	7795299
1988	37138	92.9	43626	94.3	4851	80.8	80037	8214336
1989	46338	114.7	53639	116.0	6724	112.0	98768	

In the last quarter of 1988, after 9 years of limited access to petrol, Polish government suppressed the coupon system and immediately an upward trend in traffic volumes and number of accidents was observed - despite of significant increase in petrol prices. The trend of injury and death increase was similar to that of accidents and collisions. The number of persons killed in traffic accidents in 1989 was the highest in Polish accident statistics and occurred at the car ratio of 9 persons/car. The first six months of 1990 have shown trend similar to that in 1989.

International comparison of traffic accidents, accident casualties and accident rates in 1989 indicate that the total number of deaths, killed pedestrians and fatality rates per 100 accidents are very high in Poland in comparison with those in Western European countries and Yugoslavia (Table 2). The number of accidents involving pedestrians is still very high. In 1989 there were 2820 pedestrian deaths (42% of the total deaths in traffic accidents) and 18507 injuries (34.5% of the total). These numbers of pedestrian deaths and injuries are still much higher in Poland than in other countries included in the comparison.

Table 2. International comparison of traffic accident casualties and accident rates

Country	Number of accidents	Killed		Injured	Rates of accidents	
		Total	Pedestrians		Killed per 100 accidents	Casualties per 100 acc.
France	175887	10548	1592	244042	6.0	144.7
W. Germany	342299	8213	1732	448223	2.4	133.3
Italy	166033	6939	1132	228186	4.1	141.6
Yugoslavia	45313	4555	1347	69837	10.0	144.6
Poland	46336	6724	2820	53639	14.5	130.2

Polish accident data and international comparison do highlight the problems of road traffic safety and especially pedestrian safety in Poland and traffic safety measures as well as facilities.

2. Predictive relations for pedestrian accidents

Recent accident trends, especially accident data related to pedestrian safety, forced us to study pedestrian safety. In particular, we have decided to study pedestrian accident risk at signalized intersections with a view of:

- analyzing the nature and extent of pedestrian accident factors
- developing accident prediction models

and, in the longer term, assessing the effectiveness of some remedial measures.

The general form of the prediction model links an expected number of accidents A with intermediate measures:

$$A = F(Q, P, g, c)$$

where:

- Q - volume of vehicle traffic,
- P - volume of pedestrian traffic,
- g - geometric variables,
- c - signal control variables.

The explanatory variables in the model should be connected with parameters of the design process and available for traffic engineers.

The simplest form of the model includes traffic flows only and can be used to evaluate the effects of the traffic pattern changes on accidents. The more comprehensive form

includes a set of additional explanatory variables and enables detailed analysis:

$$A = T \cdot K \cdot Q^{\alpha} \cdot P^{\beta} \cdot \exp(\sum a_i g_i)$$

where:

- T - number of years,
- Q - volume of vehicle traffic (first crossing stream),
- P - volume of vehicle or pedestrian traffic (second crossing stream),
- g - other explanatory variables,
- K, α , β , a_i - model parameters.

The form of the prediction model enables the convenient use of the generalized linear methodology, developed in the British Transport and Road Research Laboratory [2].

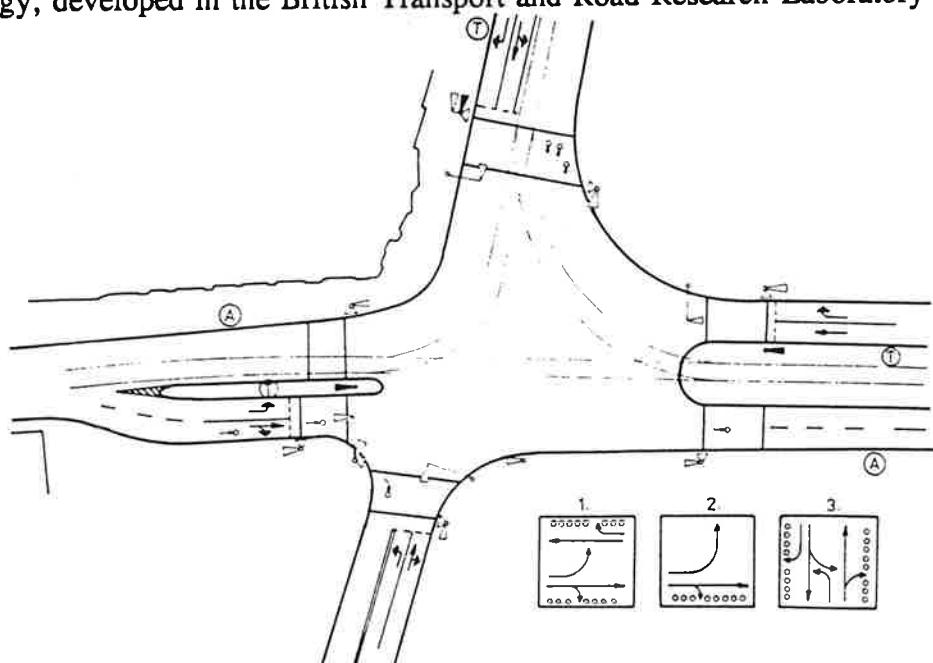


Fig.1. An example of the studied intersections

Accident data base for the development of prediction model of pedestrian accidents at pedestrian crossings included various crossing layouts at signalized intersections. The example of intersection layout (Fig.1) shows a few types of pedestrian crossings taken into account in our studies. Public transport is still very important in Poland. Stops located near a junction generate a large proportion of crossing pedestrians destined for public transport stops. Concern with pedestrian safety at signalized intersections revolves around vehicles turning movements as two-phase traffic signals are often met at Polish junctions with commonly used "turn right-on-red" provision. It means that there is conflict between vehicles turning right or left and pedestrians crossing the carriageway during their green signal.

Accident statistics suggest that 63 percent of accidents involving pedestrians occurred when pedestrians were crossing the carriageway during the red signal. The violation of the beginning of the red signal by drivers is remarkably less frequent and occurs in 7

percent of accidents. Therefore studies were focused on pedestrian movements during red signal. Measurements of vehicle and pedestrian traffic flows were carried out in 12-minute intervals at 105 crossings using manual event recorders. Then the obtained sample of 400 internals has been processed using non-linear regression technique.

The measurement has shown that, in general, the large proportion of pedestrians crosses the carriageway during the red signal, but this pedestrian behaviour depends on traffic and geometric situation what can be described by the following model:

$$P_r = 0,52 \cdot P \cdot \rho \cdot (1-X) \cdot [1 - 0.017 (w-7) - 0.135 (k-3)]$$

where:

- P_r - number of pedestrians crossing during the red signal [PS/h],
- P - total pedestrian flow [PS/h],
- ρ - proportion of the cycle that is effectively red for pedestrians,
- X - carriageway degree of saturation,
- w - carriageway width [m],
- k - number of the directions from which vehicles come.

The impact of vehicle flow, expressed by the degree of carriageway saturation is the strongest one. In his decision pedestrian takes into account the width of carriageway and complexity of traffic situation expressed by the number of vehicle streams.

The following factors were included in accident analysis:

- traffic flows and speed,
- geometric factors: public transport stops, number of traffic lanes, width of carriageway, number of directions with oncoming vehicles, distance between crossings and the stop-line for main conflicting vehicle stream, dividing island or central reserve,
- control factors: signal settings, the proportion of vehicles turning concurrently with pedestrians during their phase.

The studied sample was selected in order to provide a wide range of flows, geometric and control parameters. No specific attention was taken of accident data.

The lack of pedestrian flow data and incompleteness of vehicle flow data has forced to conduct own flow measurements. Half-hour counts were taken at all crossings. At each site two counts were taken in the morning and afternoon peak. An heuristic method based on earlier carried out long-term counts was used to estimate sixteen-hour flows from the two short-term counts.

At 105 studied pedestrian crossings 175 accidents involving pedestrians occurred in the period of 5 years (1984-1988). The computer program GLIM [3] was used for evaluation of traffic and accident data. The following regression model includes explanatory variables significant at the 5 percent level:

$$A = 0.043 \cdot T \cdot Q^{0.6} \cdot P^{0.35} \exp[0.59B + 2.6(\rho - 0.6) - 0.092(w - 7) + 1.57u]$$

where:

- A - accident number,
- Q - volume of vehicle traffic [1000 veh/16 hrs],
- P - volume of pedestrian traffic [1000 ped/16 hrs],
- B - flow of public transport vehicles stopped at stops located near pedestrian crossing [1000 veh/16 hrs],
- ρ - proportion of the cycle that is effectively red for pedestrians,
- w - carriageway width [m],
- u - proportion of vehicles crossing pedestrian stream during phase with pedestrians.

The comparison between the predicted and observed numbers of accidents is shown in Fig.2.

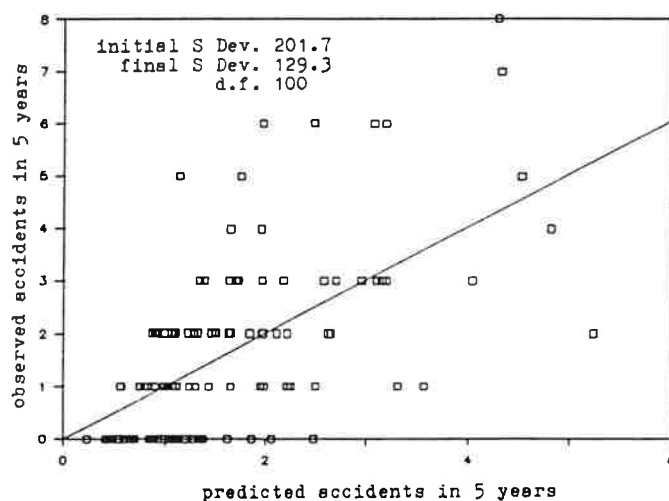


Fig.2 Comparison between predicted and observed numbers of accidents in five year

The following conclusions can be drawn from these studies:

- (1) Statistically significant relations have been obtained between the number of accidents and traffic flows, geometric and signal variables.
The obtained model enables an analysis of signalized intersection with regard to various factors:
 - refuge islands for pedestrians,
 - signal settings,
 - phase sequence,
 - location of transit stops (although, it is complicated due to effect of stops location on pattern of pedestrian flows at intersection).
- (2) We have not found significant relation between accident number and pedestrian violations of the red signal. The adaptive pedestrian behaviour could be one of the possible explanation of this phenomenon. Further studies are needed however.
- (3) Further studies on non-signalized crossings would provide signal control warrants

in point with a view of pedestrian safety.

3. Practical application of TCT

Besides of the numerous advantages and various applications in other countries, traffic conflict technique has not been popular in Poland. The purpose of the study undertaken in Cracow University of Technology was an application of TCT for studies of traffic safety at intersections and pedestrian crossings in regard to selection and adaptation of one of existing procedures - optimal for Polish conditions.

Two selection criteria have been assumed:

- the degree of fulfillment of a basic assumption of TCT by the considered procedures, that between the number of conflict situations and number of accidents exists a significant relationship and thus TCT allows in practice for accident prediction.
- accessibility for a wide range of potential users.

At first the approach described in [4] has been considered. Pilot stage of survey (training of observers) which involved 4 intersections and 2 pedestrian crossings have confirmed the usefulness of the method - especially for the qualitative description of traffic conditions. Therefore for further field surveys 10 signalized intersections have been chosen with various geometric layouts and with high accident records expressed by the number of accidents/1 million vehicles/year = 0.64 - 3.56. Data base included 3-year period and the observers collected data in 6 hours samples (2-3 recording intervals) for each intersection.

General characteristics of traffic safety at the studied intersections is shown in Fig.3 in which the distribution of various types of accidents in the sample for 10 intersections is also given. In Fig.4 similar distribution of the recorded conflict types is shown.

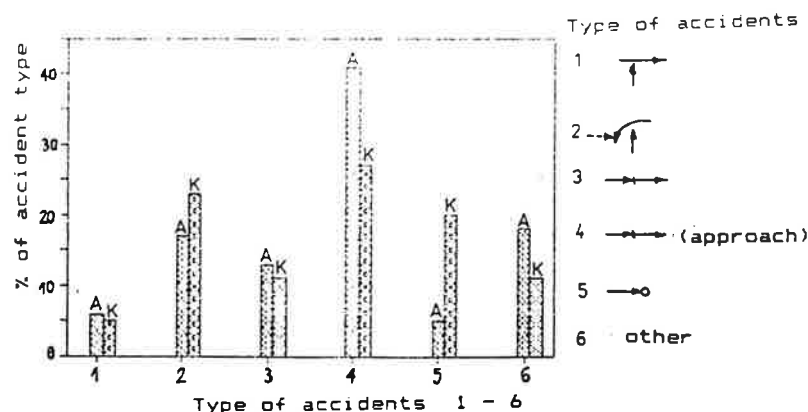


Fig.3 Distribution of types of accidents and observed conflicts at studied intersections.

Low percentage of accidents involving pedestrians (Fig.3) is caused mainly by including property damage only accidents in the total number of accidents, while

almost all accidents involving pedestrians are injury or fatal accidents.

This group of accidents shows also significant disagreement in comparison of conflicts and accidents shown in Fig.3. It can be explained by a significant number of vehicle/pedestrian conflicts occurring at low-speed, between pedestrians and vehicles turning right or moving at the beginning of the green signal, when the probability of the injury accident is low. Therefore two groups of pedestrian/vehicle conflicts associated with different speed and thus with different accident risk probability have been distinguished.

Analysis of the pedestrian/vehicle accidents and conflicts at 43 pedestrian crossings has shown that between the number of traffic conflicts K observed in 6-hour periods and accidents exists the statistically significant relationship (Fig.4):

$$A = 0.42 \cdot K_p + 0.5 \quad (\text{accidents/3 years}),$$

where the standard estimation error $\delta = 1.4$ accident/3 years.
Significant effect of random factors can be seen ($R^2 = 0.37$).

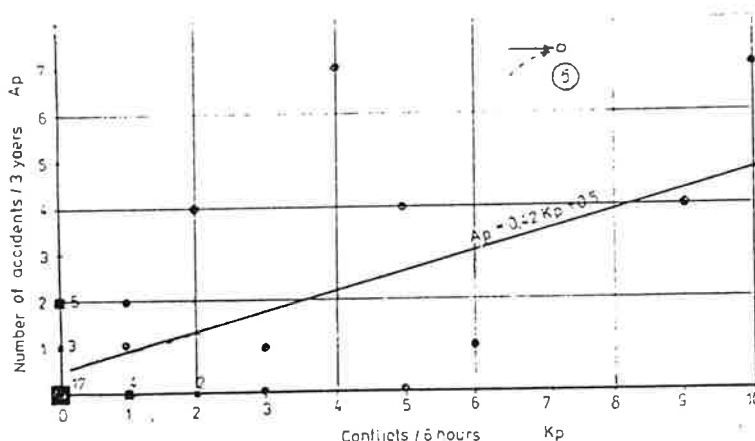


Fig.4. Relationship between number of conflicts K_p and number of accidents A_p involving pedestrians.

Accidents and conflicts of vehicles turning left at intersections are usually more dangerous. There were 26 left turns in the data base but relationship between vehicle/vehicle accidents and conflicts has not been found (Fig.5).

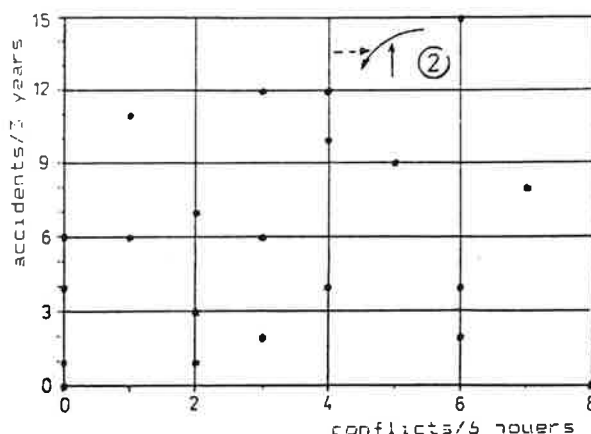


Fig.5. Comparison of numbers of traffic conflicts and accidents for left turning movement

Including the volume of the opposing streams as an additional variable associated with traffic safety and replacement AR_L and RR_L by the relative ratios gave the following relationship (Fig.6):

$$AR_L = 0.125 \cdot RR_L + 0.2 \quad (\text{acc/mln veh/year})$$

at, $R^2 = 0.24$, $\delta = 0.5 \text{ acc/mln veh/year}$

where:

AR_L - ratio of accidents (number of accidents/traffic volume/year)

$RR_L = K_1 \cdot 1000 \sqrt{Q_1 \cdot Q_2}$, where Q_1 and Q_2 are traffic volumes of opposing and opposed movements, K_1 is number of conflicts.

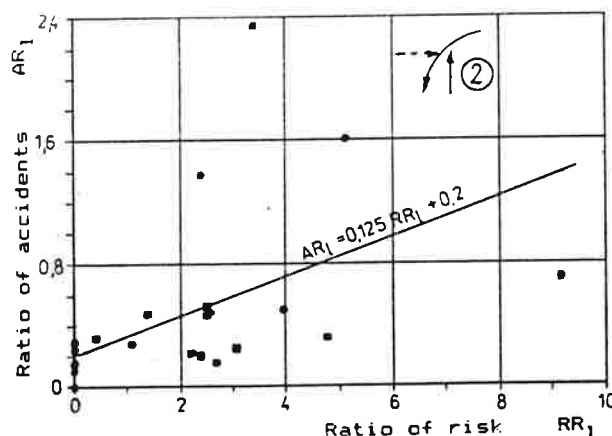


Fig.6. Relationship between AR_L and RR_L

Due to the limited data base the evaluation of the developed relationship should be very careful. Results however are so encouraging that further studies towards the development of Polish TCT guideline are planned. Two remarks can be drawn from this TCT survey:

- (1) classification of conflicts according to the level of rapid avoiding movement assumed in the used method [4] does not give practical results due to a small

number of conflicts recorded in group 2 and 3 in the 6-hour period of observation. To obtain a sufficient sample size of conflicts from groups 2 and 3, the observation period 4-6 times longer that used should be applied, what makes the method less attractive.

- (2) classification of traffic conflicts based on the features characterizing the risk of accident (speed for example) seems more practical.

4. Final results

Accident prediction models and traffic conflict technique seem very useful and attractive tools for traffic engineers in cost-effectiveness evaluation of intersection and pedestrian crossing design. However, some practical calibration especially in conflicts classification are justifiable.

Other studies of traffic safety related to interactions of intersection users conducted in Cracow University of Technology are related to the use of clearance times (i.e. yellow and all-red intervals) by drivers and flashing green and red by pedestrians. It has been found that whole yellow interval and even the beginning of red are used by drivers to enter the intersection.

These and other phenomena should be included in new guidelines.

References

- [1] Ministry of Domestic Affairs, Road accidents in Poland in 1989, Warsaw 1990 (in Polish)
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- [3] Baker R.J., Green M., White R.P., Generalized Linear Interactive Modelling (GLIM-3.77), Royal Statistical Society, Oxford 1987.
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