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Summary
Free market economies have shown the dominating utility of motorized transport, both for passenger and goods transport. One negative side of motorization is the lack of road safety. Although it is shown that air, water and rail transport are much safer, the individual and company utility of motorized road transport is so high that in free market economies transport by car has become the major mode of transport for goods as well as for persons. Nonetheless the safety importance of a transport mix which includes public transport for persons and rail or ship transport for freight must be recognized.

Countries are on different development levels in motorization and road safety. It is argued that growth of motorization is accompanied by enlarged and improved road infrastructure, more experienced drivers and improved traffic regulations. Consequently the risk of fatalities in road traffic decreases the more mobility grows. If the relative increase of growth is larger than the decrease of the risk, the number of road fatalities is increasing, while the reverse also holds. The former now holds for Central and East European countries, the latter for the USA and North-West Europe.

A national road safety policy must be directed towards a high annual reduction of risk per distance travelled. This only can be achieved together with a growing kilometrage if the road infrastructure is improved and traffic becomes redistributed over roads with lower risk levels. Influencing the driver by improved driver training and safety campaigns is a prerequisite, but contrary to the general belief they have not shown to be very effective safety measures on its own. However, police enforcement with a certain intensity level on drunken driving and violations of speed limits (at least one annual control out of three license holders) can be very effective. A national plan which activates national, regional and local authorities for effective road safety can not only reduce the immense loss of human lives and the sorrow over them, but also save the waste of the huge costs involved. In the European Community the costs of the lack of road safety is about 70 billion ECU. Investments in road safety, therefore, pays off more than one usually is assumed.

Introduction
Free market economies imply the transport of individuals and goods. Goods will be produced on locations with the lowest production costs and consumed elsewhere. People will be free to choose to live on other and often nicer places than production areas, but still have to go from home to working places. Generally they try to select working places which offer the highest salary or income possibilities and despite efforts of regional planning these working places tend not to be the ones most close to their homes. In general economic growth in free market economies also show a corresponding growth in traffic. Since motorized road transport is the only way of transport which enables one to transport goods and persons from door of origin to door of destination in relatively short times, it generally has a higher utility for individuals and companies than other transport modes over moderate distances. Only for passenger transport over relative long distances

(larger than about 400 km.) high speed trains or air travel is favoured. Rail or ship transport for goods is only dominating for heavy bulk materials. Apart from physical and economic impossibilities, length of travel time for persons and physical limitations for goods are the only factors which may lead to an other choice of transport mode than road transport. Therefore, with growing economic possibilities people will buy more and more cars and travel more and more by car, while companies tend to deliver their goods more and more by vans and trucks. Individuals will use their cars not only for business and home-work trips, but also for social and tourist trips and more so the more the economic situation improves and leisure time increases.

This asks for an enlarged, improved and well maintained road infrastructure. In democratic countries such a renewed and enlarged road infrastructure will be established by the pressure of the voting people which favour road transport in growing free economies for the reasons just given. The national, regional and local authorities have to provide that infrastructure in order to fulfil the democratic needs on the one hand and on the other hand to make economic growth possible. In modern terms the systems of free market economy, transport and democracy constitute a self-organizing macro-system (Jantsch, 1980) in which these subsystems pull and push the macro-system evolution (Koornstra, 1992). Under the condition that the resources are available the course of the macro-system evolution leads more or less autonomously to a growing road transport for persons and goods. The renewal and enlargement of the road infrastructure generally will be delayed with respect to the societal needs and actual growth of road traffic, due to the scarcity of means and the time needed for planning and design, for decision taking on several levels and last but not least for actual (re)construction. Such an adaptation delay with respect to mobility growth can lead to serious problems as developments in road safety show.

Safety Comparison between Modes

The road system evolved gradually from the network that was originally fitted for carriage and pedestrian travel. Motorization changed the road system drastically, but the road transport system has never been designed in such a way that the opportunity for accidents is prevented a priori, like it has been for rail- and air-transport. Rail and air passenger transport are more than a factor of 200 times safer than passenger transport on European roads.

mode	area	fatality rate p. pass. km.
road	Eur. Comm.	3.5×10^{8}
rail	West Eur.	1.6×10^{-10}
air	USA	0.4×10^{-10}

Table 1. Risk per transport mode.

The Central and East European countries used to have a relative well developed railway system and in view of the need of a safe transport it is important not to abolish that mode of passenger transport. Although the share of passenger transport by train will reduce with the fast increasing motorization in Central and East Europe, it will be advisable to keep the level of this mode at least on its absolute level. It may prevent partially the problems of increasing congestion in the future and certainly contributes to overall transport safety.

Safety Comparison between Countries
The developments of road safety and motorized mobility over long periods of time in many countries recently have been analyzed and successfully modelled on the basis of the evolutionary principles of time-dependent macro-system growth by Oppe and Koornstra (Oppe & Koornstra, 1990; Oppe, 1991a; Oppe 1991b; Koornstra, 1992a). According to their analysis the differences between countries in road safety are largely dependent on the past history of motorization growth in a country. Countries with a relative early and more or less uninterrupted growth of mass motorization, like the USA and Great Britain, show the lowest fatality rates as the ratio of annual road fatalities and annual total of vehicles kilometres of the country. Also the higher the growth rate of motorization is the more the fatality rate decreases as the post World War II developments in countries like Germany, France, the Netherlands, Japan and many other countries show. Although economic long term developments deter and accelerate these developments in motorized mobility and road safety risks, the underlying macroscopic developments in vehicle kilometres has been successfully described by a saturating S-shaped curve and the development of the fatality rate by an exponential decreasing curve.

The product of vehicle kilometres and fatality rate gives by definition the development of the fatalities, which according the underlying time-dependent curves should necessarily show a single peaked curve for the development of the road fatalities. In the starting period of development the percentage of growth in vehicle kilometres is large, but that percentage diminishes gradually. The percentage of decrease in the underlying fatality rate, however, is constant. As a consequence somewhere in the course of these developments the fatality rate reduction becomes larger than the growth rate in vehicle kilometres. Before that point in time the number of fatalities will increase and there after decrease. For the early industrialized countries (USA and North-West Europe) that turning point lies in the first half of the seventies. Therefore, nothing else than these two regular developments in mobility and fatality rate is needed for the explanation of the peaked development in fatalities in many countries. Although the long term macroscopic developments in mobility and fatality rates are quite well described by this modelling (for example in the USA from 1923 to 1990, see Koornstra, 1992a) the product of these macroscopic trend curves do not accurately predict the annual numbers of fatalities retrospectively, due to the observable deviations from the underlying macroscopic trend curves.

Analysis of data from several countries has shown that the deviations from these curve can be modelled by a simple cyclic modification of the underlying trend curves. The same cyclic pattern which governs the deviations from the exponential decreasing fatality rate has a delay of a quarter of the period compared to that cycle around the S-shaped growth of vehicle kilometres. This means that a periodically larger increase in vehicle kilometres is followed by an overlapping stagnation in the decrease of the fatality rate. The deviations from the monotonic developments in mobility growth and fatality rate in the USA for the after World War II period can be described by cyclic pattern with a period of 18 years. Figures 1 and 3 show the analysis and prediction from the analysis of trend curves with a cyclic modification for the USA from 1949 onwards. The same type of analysis is presented for Japan in Figures 2 and 4, where the period of the cyclic modification of the monotonic trends is 36 years. The actual fatalities and the retrospective and prospective prediction of the fatalities by the product of the curves from Figures 1 and 3 for the USA are shown in Figure 5 and by the product of the curves from Figure 2 and 4 for Japan in Figure 6.

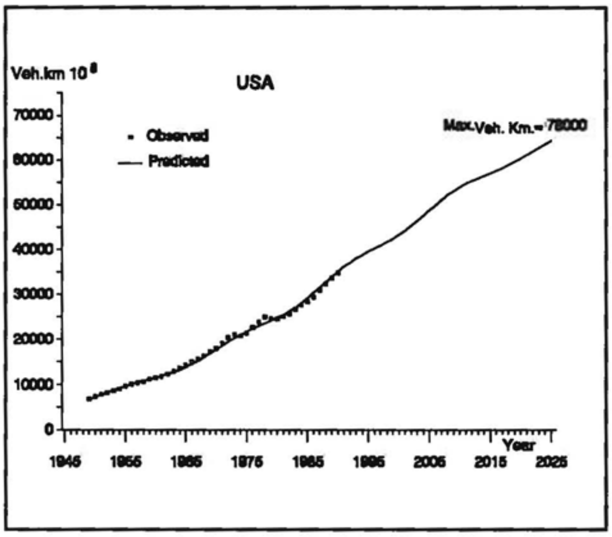

Figure 1. USA: Vehicle Kilometres.

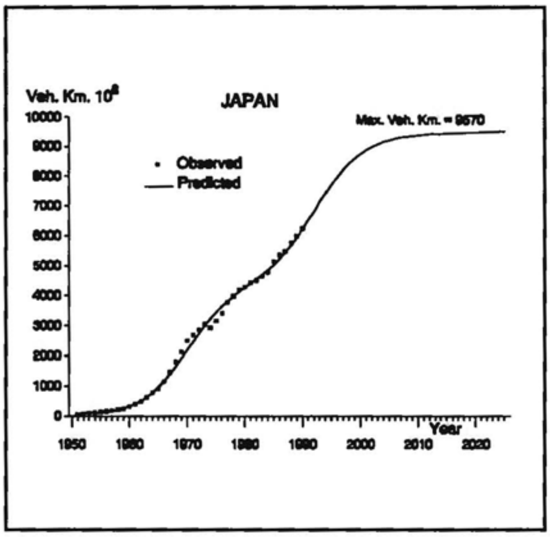

Figure 2. Japan: Vehicle Kilometres.

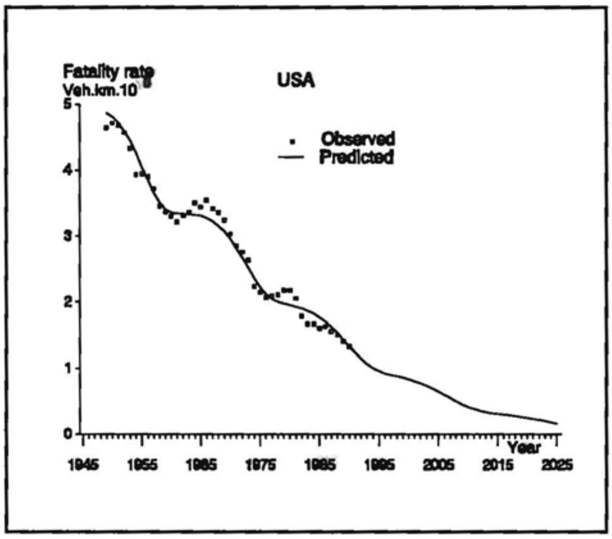

Figure 3. USA: Fatality Rate.

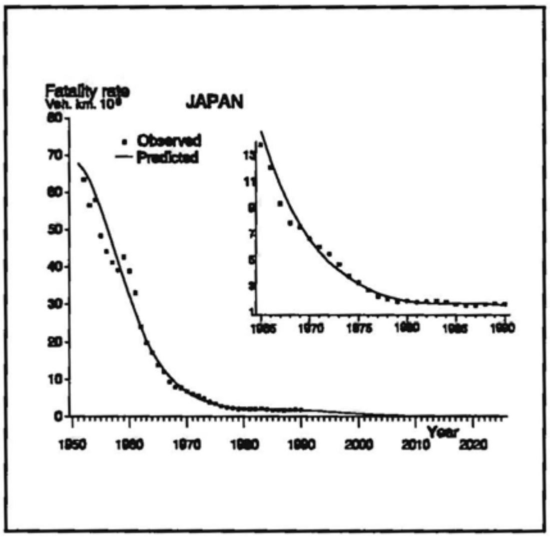

Figure 4. Japan: Fatality Rate.

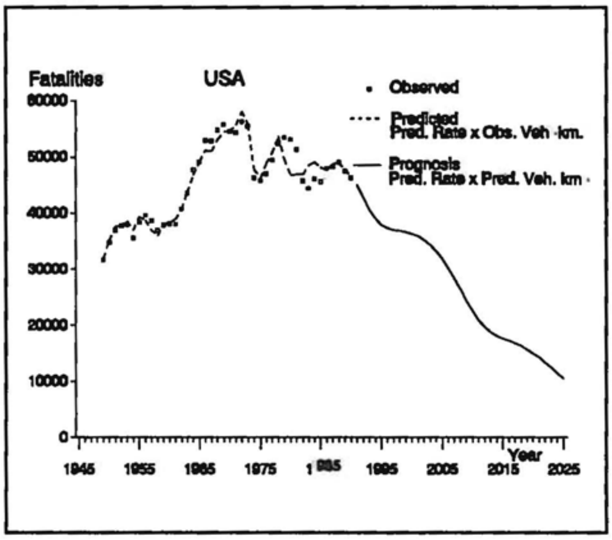

Figure 5. USA: Fatalities.

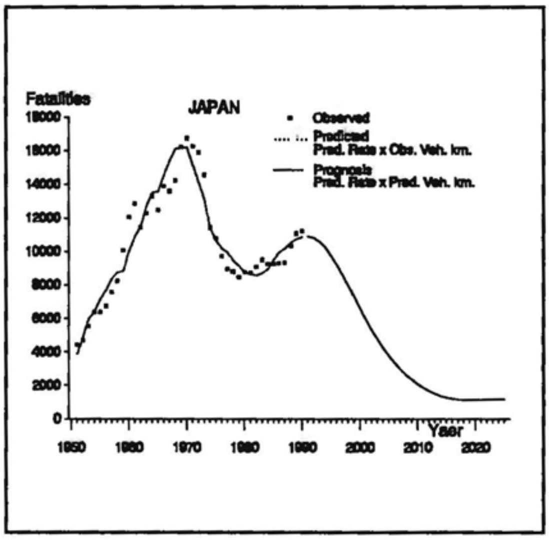

Figure 6. Japan: Fatalities.

The comparison between the USA and Japan illustrates several general things. Firstly, it illustrates that the development in fatality rate is dependent on the development in mobility. The annual reduction in the fatality rate in the USA is in the mean 3.3% and in Japan 8.5 %, but also the slope of mobility growth in Japan is also about 2.5 times steeper than in the USA. Secondly, the analysis show that the number of fatalities is mainly dependent on the level of the increase in vehicle kilometres (with a delay) and not on the absolute level of kilometrage. Therefore, Japan shows two main peaks in fatalities just after the two periods of largest increase in vehicle kilometres around 1970 and 1990, where as for the USA a single main maximum level modulated by several smaller peaks between 1970 and 1990 is observed. Last but not least the starting period of the developments for the USA lies far before World War II, whereas for Japan it lies just thereafter. As also the analysis of other countries shows the mechanisms are the same, only the development for different countries is phased differently in time. The development in the USA is about 30 years earlier than in North-West continental Europe. The developments in Central-East Europe have been deterred until recently and can be seen as about 30 years lagged in comparison with North-West Europe as an analysis for Central-East European countries by the same methodology has shown (Koornstra, 1992b).

Figure 7 shows the result for Poland with regard to the development in passenger cars, where it is assumed that the saturation level of motorization will be the same as the one for (west)Germany (1.4 inhabitant per car), since that level can not be estimated from the too short series of the available data. The cycle around the S-shaped mobility curve as well as the exponential decreasing fatality rate (Figure 8) for Poland is estimated to have a period of 40 years, which is about the same as for (west) Germany. If the saturation level is reduced by some percentage than the maximum of the expected fatalities is also

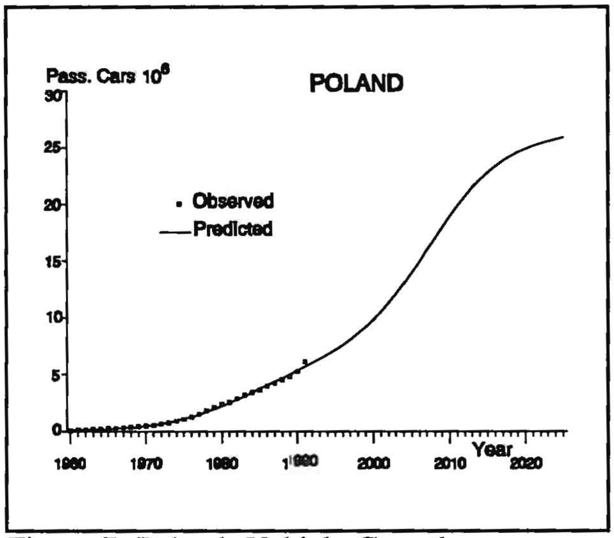

Figure 7. Poland: Vehicle Growth.

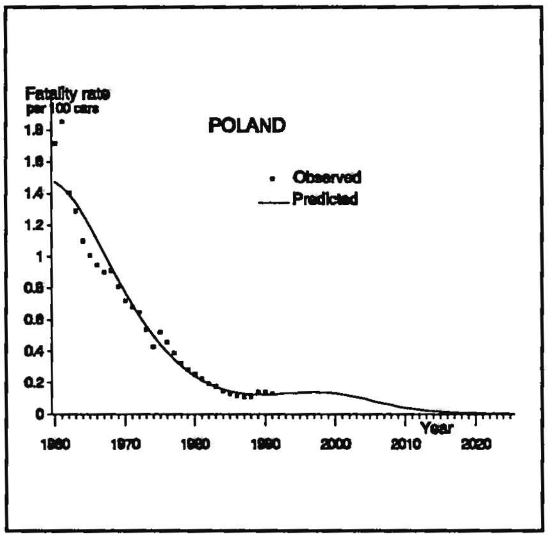

Figure 8. Poland: Fatality Rate per Car.

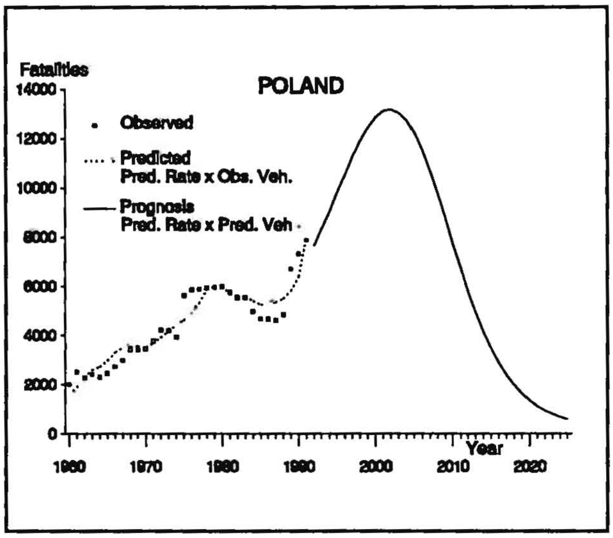

Figure 9. Poland: Fatalities.

reduced by nearly that percentage. The fatality rate per car for Poland reduces in the mean by nearly 8 % annually. The achievement of such a reduction in fatality rate will only be possible in the future if the further growth in mobility is accompanied with an effective road safety policy. But even with an ongoing 8% annual reduction in fatality rate the number of fatalities will increase if the percentage of traffic growth in the next period is larger than 8%, as in fact it is predicted to be up to 2004 in figure 7.

Safety Comparison between Road Types

Despite the gradual upgrading of the road system it everywhere still is a network of roads which constitutes a concatenation of a nearly endless variety of road sections by an also endless variety of cross-connections. The result is a road system which is too complex for the road user to allow reliable predictions for the next oncoming situation. Only the design of modern motorfreeways permits relative reliable predictions. Since this road category is relative well predictable and also because the variation in speed is relative low (extra shoulder lane for emergency stops, no level junctions and no opposite and only motorized traffic) it is a relative safe type of road, in spite of the high speeds driven. The fatality rate per kilometrage on motorways approximates the safety of rail transport. The same level of safety holds for well designed residential calming areas, where speeds are so low that the variation in speeds between all road users is also low.

Road type	Max. km/h	Mixing fast/slow	Level junctions Opposite traffic	Injury rate mill. km	Fatality rate 100 mill. km
calming area	< 30	yes	yes	0.20	< 0.3
resid. street	50	yes	yes	0.75	1.2
urban arterial	50/70	yes/no	yes	1.33	2.5
rural road	80	yes/no	yes	0.64	4.6
rural motor road	80	no	yes	0.30	2.1
rural motor road	100	no	no	0.11	1.7
motorfreeway	100/120	no	no	0.07	0.5

Table 2. Injury and fatality rates of road categories in the Netherlands 1986.

As can be seen from the above table of injury and fatality rates on Dutch roads, all other road types than motorways and calming areas have considerable higher rates. The lack of safety varies with the combination of the level of speeds and the amount of variation in speeds due to discontinuities (level junctions and opposite traffic) and mixture of slow and fast categories of road users on the road type. The rural roads have the highest fatality rate and the urban arterials the highest injury rate. Although for Poland such detailed data are not available the applicable rates will be higher, since the total fatality rate per 100 million vehicle kilometres for Poland is estimated to be between 7.5 and 9.0 (Gerondeau et al., 1992) and the Netherlands as one of Europe's most safe road networks has a total fatality rate of 1.7 in 1986 (1.3 in 1992). However, the difference pattern for road types probably will be comparable, despite the largely absent categories of motorfreeways with modern standard design and traffic calming areas in Poland. A modern upgrading and enlargement of the motorfreeway network in Poland will not only be necessary for reasons of the increasing road transport needs, but it also will redistribute the traffic towards this safer road type and away from the dangerous rural roads. This in itself would have a large positive effect on the national road safety. The road safety in built-up areas could be improved markedly by the construction of by-pass roads around villages and towns for the otherwise trough-going traffic. The road safety in residential area itself can benefit tremendously by the consistent introduction of traffic calming areas and pedestrian zones in towns and larger villages. Dutch evaluation research has even shown that calming areas can reduce 90% of the injury accidents in the area and Table 2 shows in comparison to residential streets a nearly 75% reduction in injury rate. The redesigning of the road categories between motorways and residential calming areas to a limited number of categories of self-explaining roads with well predictable uniform layouts of routes and crossing types is also most urgent. This is the major long term task which should be undertaken in a national coordinated way, since diversity between regions contributes to unpredictability.

The ingredients of a relatively low cost reconstruction and enlargement of such a safe road network for Poland still ask for more research, but some basic principles are known to be essential. Separation of slow and fast traffic and traffic with large mass differences is one of the safe design principles. This means pedestrians on sidewalks only and preferably cyclist on separated cycle paths, while crossings for pedestrians and cyclists on rural main roads and arterial urban roads preferably should be designed as grade-separated crossings. It also may become to mean special truck routes for inter-regional heavy good transport and limitation of masses of trucks in urban areas, where delivery by smaller vans from just-in-time transit centres outside towns may be foreseen in the long run. Separation of tracks for opposite traffic on rural main roads and urban arterial routes by guardrails is also needed in the future, combined with reconstructed crossings and accesses to these roads. A typical problem for Poland seems the number of access entries to rural main roads for agricultural traffic; this number should be reduced by separate low cost paths and preferably also by regional plans for land exchange between farmers. Research with respect to crossings in France and the Netherlands has shown that the British roundabout with priority for roundabout traffic is a much safer level crossing than non-signalized as well as signalized junctions. Reductions even of 90% of injury accidents have been observed after reconstruction of junctions to roundabouts. The relative low share of fatal car-car accidents in the UK, compared to other Western European Countries may be explained by the frequency of the British roundabouts in their road network. The Polish authorities could learn from other countries how their relative high share of fatal pedestrian accidents can be reduced by safer road constructions for these road users as well as for cyclists. There is a long way to go before such a renewed road categorization will be established. The first steps, also according to the World Bank report (Gerondeau et al., 1992) on road safety in Poland, are the conceptual creation of the hierarchical structure of the categorized and homogenized road network and the clarification of its principles on a national level. In that report it is proposed to begin with the introduction of a systematic, periodical inspection of the safety of the roads and to prepare and disseminate reference material with all the principles for a modern upgrading to the safest-possible road network by building new roads and improved maintenance and reconstruction of the existing roads.

Safety Comparison between Drivers

Driver education is a prerequisite, but different driver licensing requirements have not shown that road safety is very much influenced by these differences. The risk for new drivers drops the more kilometres are driven and only stabilizes on a lower risk level after more than fifty-thousand kilometre driving experience. Safe driving can only be learned by much practice. Information campaigns on road safety, especially those which are not directed to specified behaviours and/or are not sustained by intensified police enforcement on the specific behaviours, are only temporarily or not at all effective. Lack of seat belt wearing, overspeeding and drunken driving, however, are main behavioural areas where road safety can be improved effectively. Seat belt wearing has shown to have an effect of about 40% on the risk of an fatal outcome from a car accident (Evans, 1991). The level of blood alcohol while driving has shown to have an exponential increase on the risk of casualty accidents, as the often confirmed study of Borkenstein (Evans, 1991) has shown. For example the fatality risk with 1.2 promille blood alcohol is about 6 times higher than for sober drivers. The proportional reduction of the mean speed has a double quadratic effect on the proportional reduction of fatalities (Nilsson, 1982). This means that a 10 % reduction in mean speed (0.9) will have a 35% reduction in fatalities (0.9^4=0.65) Also speed differences are parabolic related to the risk of accidents (Solomon, 1964: Cirillo, 1968). Mean speed is more related to the severity of accident outcomes and speed variance to the frequency of accidents. Adequate speed reduction and homogenization of speeds are both very important for road safety. Because of the relation between speed and road safety, the speed limits for the roads in built-up areas and the rural roads in Poland should be reduced to respectively 50 and 80 km/h. Intensified police enforcement with a high efficiency by automatic devices (speed violations) or by visible controls of randomly selected road users on unpredictable places and times (driving under the influence of alcohol) and combined with information campaigns have shown (Koornstra, 1992b) that these dangerous behaviours can be influenced markedly. Large effects on the reduction of casualties and fatalities are observed if the intensity level of enforcement becomes above one out of three license holders controlled annually.

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