Predictions of road safety in industrialized countries and Eastern Europe

M.J. Koornstra & S. Oppe

D-92-11

PREDICTIONS OF ROAD SAFETY IN INDUSTRIALIZED COUNTRIES AND EASTERN EUROPE

An analysis based on models for time series of fatality rates and motorized vehicle kilometers or amounts of passenger cars

Paper presented at the International Conference 'Road Safety in Europe", Berlin, 30 September - 2 October 1992

D-92-11
Matthijs J. Koornstra & Siem Oppe
Leidschendam, 1992
SWOV Institute for Road Safety Research, The Netherlands

ABSTRACT

Long term developments in growth of motorized mobility and accompanying developments in fatality rate (and injury rate) can be rather well described by relative simple functions of time. These functions are monotonic trends modulated by a cyclic wave function with a long period. The monotonic trends are sigmoid curves (logistic function) for saturating growth of motorized kilometrage and decreasing curves (exponential function) for risk adaptation. Analyses of data for many countries have shown that the parameters of the cyclic waves around these trends, as well as the trend parameters themselves, are related. This relation implies that the cyclic increase above trend in motorization is followed by a cyclic stagnation of the adaptive risk reduction (or even a temporary risk increase). With respect to safety this can mean a simultaneous combination of relative large increases in vehicle kilometers and an increase in fatality rate, which is disastrous.
The relation between mobility growth and risk adaptation is theoretically understood as the result of a technological evolution under socio-economic constraints. Differences in developments between countries are interpreted as differences in onset, speed and modulation of that technological evolution due to different socio-economic constraints. This, as well as the remarkable fit of the model and the relation between growth of kilometrage and risk adaptation, are illustrated by results for Japan, Germany (west) and the USA for time series of 40 year and longer.
For Eastern Europe it is argued that, due to socio-economic constraints in Eastern Europe up to now, the trend for the technological evolution of motorization is retarded socio-politically and that its cyclic wave function expresses the socio-economic repression of the last decade. The socio-political constraints in Eastern Europe are released nowadays and it can be assumed that the economic repression will turn into an upsurge in the next decade. A quantitative analysis show that these expectations are reflected in the growth of motorized mobility up to now and in the future. The analysis also confirms the close relation between mobility growth and risk adaptation from which the development of the fatality rate in the future can be deduced. An analysis is shown for the countries of Hungary, Poland and the Czech and Slovak Republic(s). The tentative results show a disastrous development of road fatalities in the next decade and a fast safety improvement thereafter. Some thoughts are given to means which may prevent these worse outcomes for the near future, but the possibility for success is doubted.

1. <u>INTRODUCTION</u>

The history of the annual number of fatalities in road traffic for the industrialized countries generally shows, besides some irregularities, a peak in the beginning of the seventies. Although many attempts have been made to explain the safety improvement after the mid seventies, it can be shown that the single peak is the necessary result of an initially high, but monotonic ever decreasing, percentage of growth in motorized kilometrage and a constant percentage of decrease for the fatality rate. This can be illustrated by the typical curves of Figure 1, which in fact contain the actual data from the Netherlands.

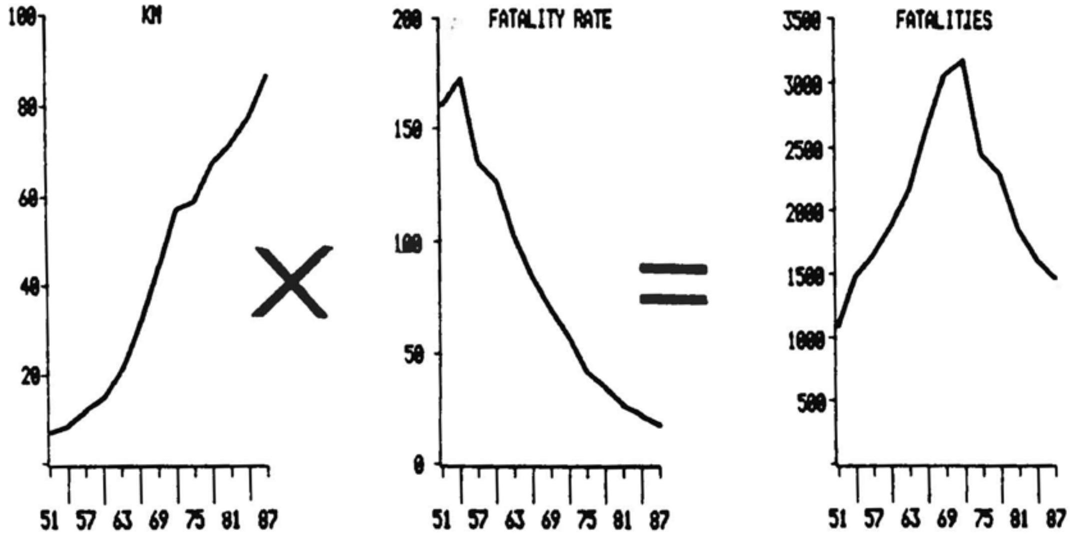

Figure 1. Typical curves for kilometrage x fatality rate = fatalities.

In fact the development of motor kilometers can be fairly well expressed by a logistic function of time (Oppe, Koornstra and Rosbach 1988, Koornstra 1988; Oppe 1989; Oppe & Koornstra, 1990). As an illustration the mileage data from the USA and their fit to the logistic function of time are shown in Figure 2.
The data for the USA are chosen for the illustration of the macroscopic validity of the logistic function for mobility growth, because it is the country with the longest history of registration e.g. from 1923 onward.

The macroscopic developments of the fatality rate for many countries have been often described by an exponential decreasing function of time

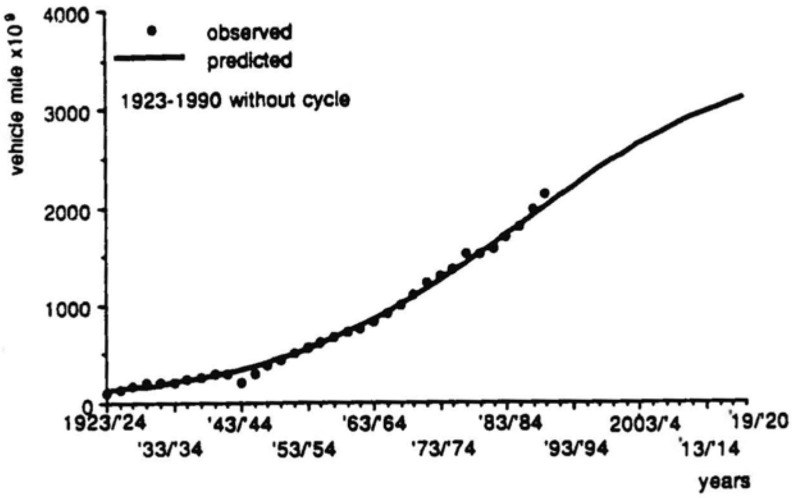

Figure 2. Logistic development of mileage for the USA.

(Chatfield, 1987; Koornstra, 1987; Broughton, 1988; Haight, 1988, Oppe 1989). Although the use of the simple exponentially decreasing function assumes implicitly that the fatality rate as a probability measure reduces to zero in the end, it has shown to be a function which in a macroscopic sense fits the data for all countries rather well. As an illustration the figure of the analysis of Chatfield (1987) for the fatality rate in the USA from 1925 to 1985 is copied as Figure 3.

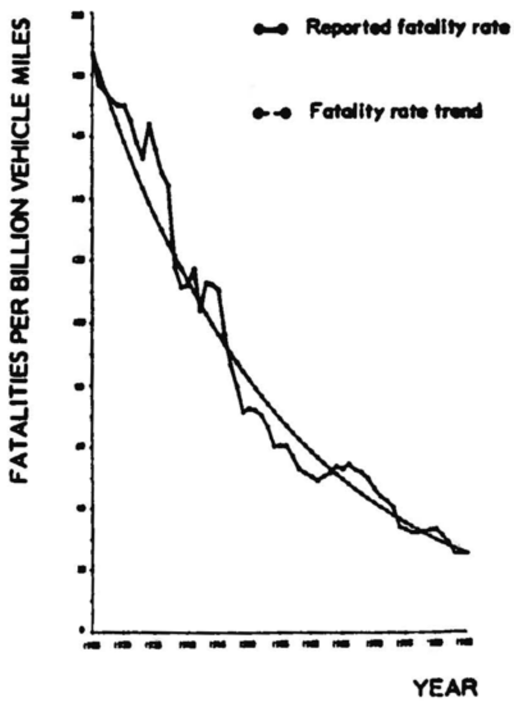

Figure 3. U.S. motor vehicle traffic fatality rates (Chatfield, 1987).

Since both functions for mobility growth and for fatality rate are functions of time, while time is perfectly predictable, one can predict the macro-development of fatalities from the fitted curves of these simple models. So has been done by Oppe (1989; 1991a) for the USA, Japan, Germany (west), Great Britain, Israel and the Netherlands, based on the data for time-series of the post second world war period of more than 40 years. From the above pictures and these analyses it can be seen that the actual developments show marked deviations from the model curves. The product of both fitted curves necessarily show a smooth single peaked curve as the expected number of fatalities from the model outcomes. As an illustration the retrospective and prospective prediction for the USA by these macroscopic models is shown in Figure 4, where the retrospective part is shown also by the actual vehicle mileage multiplied with the model prediction of the fatality rate. The fact that the fatalities in the second world war period are well predicted on the basis of the actual mileage indicates that the development of the fatality rates in the USA, in contrast to mileage, is not very much influenced by the war.

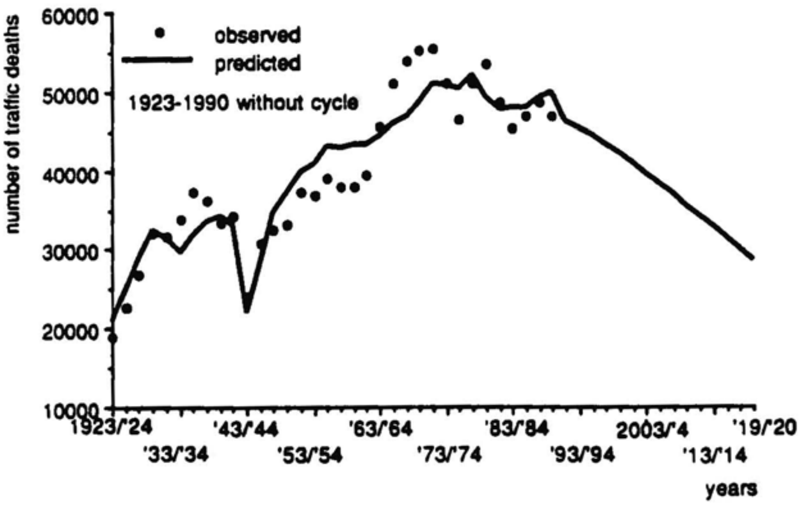

Figure 4. Macroscopic model prediction of U.S. fatalities

As can be seen the retrospective prediction is far from accurate, but it does reflect the macroscopic trend in the development and the prospective trend is one of increasing safety, because of the ever decreasing fatality rate to a virtual zero level in the infinity of time.

2. THEORETICAL BACKGROUND

On the basis of theoretical considerations from evolution theory there may exist a relation between growth and risk adaptation. In evolution theory Teilhard de Chardin was (to our knowledge) the first who has formulated such a general, more or less quantitative relation when he wrote: - "The <evolution> process for very large aggregations - as is the case for the human mass - has the tendency to 'evolve errorless', because on the one hand of chance the probabilities of success increase, and on the other hand of freedom the probabilities of refusal and failure decrease, proportional to the multiplicity of the related units" - (Teilhard de Chardin, 1948, Postscript Section 3). Applied to the technological traffic system the growth in kilometrage may be related to risk adaptation as the decreasing fatality rate. At an aggregate level and over a long period of time one may view traffic and traffic safety as long-term changes in system structure and throughput. Renewal of vehicles, enlargement and reconstruction of roads, enlargement and renewal of the population of licensed drivers, changing legislation and enforcement practices and last but not least changing social traffic norms in industrial societies are phenomena which are largely driven by growth of motorization and mobility. In an evolutionary systems approach these phenomena can be conceptualized as replacements of subsystems by sequences of better adapted subsystems within a total traffic system. The steadily decreasing fatality rate can be viewed as the lagged adaptation of the system as a whole.

Oppe found an empirical relation between the rate parameters of both developments. Koornstra realised that the resulting expression showed that the development of risk was related to the derivative of the logistic function. Working for several years on an evolutionary interpretation of social systems, he was inspired to look more generally at the quantitative relations between system growth and risk adaptation. The mathematical expressions for logistic growth of mobility and for exponentially decreasing fatality rate are related, such that the possible further growth divided by growth achieved is also an identical exponential function (Koornstra, 1988). Koornstra has shown (in Oppe et al., 1988) that, if the parameter for the slope of the fatality rate curve is half the value of that parameter for the growth curve, the number of fatalities than becomes a proportional function of the derivative of growth in kilometrage and does not dependent on the absolute level of kilometrage.

The empirically found relation between the rate parameters is illustrated by Figure 5, taken from Oppe (1991a).

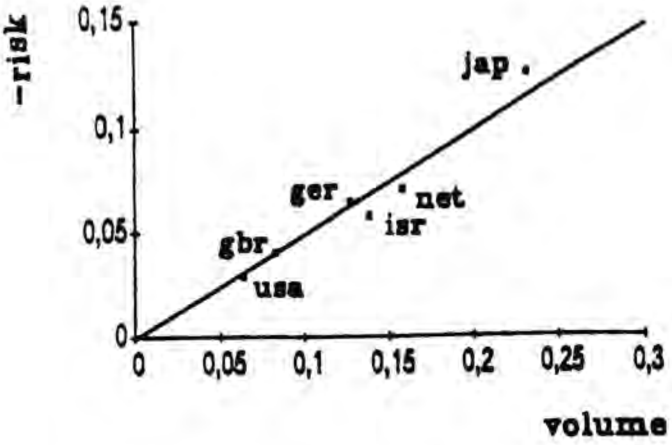

Figure 5. Relation between slope parameters for volume and rate.

The meaning of this figure that the slower the growth of mobility is the less the reduction in fatality rate is. It can also be seen from this figure that growth is slower (and risk adaptation less) the longer the unbroken history of motorization is, which is exemplified by the range of the positions from the USA to Japan. It seems, therefore, that the more recent the motorization is the larger the annual decrease in fatality rate and the more explosive the motorization is. This also may explain why for example Spain does not show its peak in fatalities at the onset of the seventies, but at the late eighties; the evolution of motorization in Spain just started later with respect to North-West Europe.

The product of the macroscopic model curves with their marked deviations as the resulting retrospective predictions of fatalities, such as the one shown for the USA in Figure 4, exhibit even relative larger deviations than the underlying pairs of curves for mobility growth and fatality rate. This indicates that the deviations from pairs of curves per country are not uncorrelated. Oppe (1991b) analyzed the residual deviations of the two curves and demonstrated that these are indeed correlated. He also showed in a model free way by polynomial analysis of curves as well as their derivates, that indeed that changes of increase and decrease in the respective actual curves are strongly correlated, which enabled him to predict retrospectively the development of fatalities in a much more accurate way.

In an earlier study we have modelled the deviations of logistic growth as a function of time also by cyclic waves are around the evolutionary S-shaped trend (Oppe & Koornstra, 1990). In that study this was done by cyclic variation of the estimated saturating level of kilometrage. This method improved the prediction of motorized mobility and fatalities considerably, although the deviations of the fatality rate were left untouched. However, this model for deviations does not and can not contribute to an intrinsic correlation between deviations in growth and rate. The intrinsic correlation between deviations for the fatality rate and the relative increase of mobility growth is nicely illustrated by Figure 6. This figure shows for the post second world war period in the USA the actual fatality rate and the smoothed, so called acceleration of growth which is the smoothed annual actual increase of growth divided by the actual growth level itself. As such both curves in this figure are curves of observed values without fitting any model to the data.

Figure 6. Observed fatality rate and acceleration of growth in the USA

This figure shows a cyclic deviation around the exponential fatality rate of Figure 3. It also shows that there are also cyclic deviations from a monotonic decreasing relative increase of mobility growth. A monotonic decrease for the relative growth increase is the mathematical result of the logistic function for the S-shaped growth itself. As can be deduced from this figure the cyclic deviations in both curves are strongly correlated. Since acceleration is a function of the derivative of the growth curve, it demonstrates that not only the macroscopic overall trends of growth and risk adaptation are related, as shown by Figure 5, but that also cyclic deviations in both curves are related. The common cycle around these curves can also be described as a function time. It seems as if relative higher growth of mobility above the S-shaped trend results in a less well adapted traffic system with a temporary stagnated or even increased fatality rate.

This inspired Koornstra (1991a; 1991b; 1992) to develop, on the basis of evolutionary relations between growth and adaptation, an integrated model for related cyclic deviations from logistic growth and exponential risk adaptation. In these studies the model parameter for the slope of the curves is cyclic varied as a function of time. This can be interpreted as long term cyclic influences on the speed of growth and speed of risk adaptation. In this integrated model not only the derivative of the growth of growth curve is related to the exponential fatality rate, but also the derivative of a cycle around the S-shaped growth curve is related to a cycle around the exponential fatality rate. The derivative of the cycles around macroscopic trend are cycles which are shifted by a quarter of the cycle period. This means that the cycle around the fatality rate will show a time lag of a quarter of its period with respect to the cycle around the S-shaped growth curve. Such a lagged influence of growth on safety can be understood as the lagged safety result from enlarged and improved infrastructures, renewal and enlargement of car fleets, revised and improved laws and improved licensing, education and enforcement practices. All together the technological evolution of road traffic is pushed by the demand for traffic and indeed do make the growth of traffic possible. The safety effects of these sequences of replacements in the traffic system are lagged in time with respect to the growth of traffic, because the realization of needed and planned changes asks for a certain time periods before the implementation is completed. Since in the integrated evolutionary model the macroscopic trend curves and the common cyclic deviations around these trend curves are both function of time, it enables us to predict retrospectively as well as prospectively the developments in growth and rates in a much more accurate way. It results in a marked improved prediction of the past and future development of road safety. This is shown in the next sections. The deviation cycles around macroscopic trends are interpreted as economic circumstances with relative long cycle periods which alternatingly deter and accelerate the technological evolution of system growth and risk adaptation.

3. FORECASTS FOR INDUSTRIALIZED COUNTRIES

3.1. Japan

In Figure 7 below we show the observed motorized kilometers (given as dots in the figure) from 1951 to 1990 in Japan and the predictions by simultaneous fit of logistic trend and cyclic deviations (given as a solid line). In order to show the influence of the cyclic deviations the underlying sigmoid curve is also presented (intermitted line). The optimal cycle has a period of 36 year and the saturating growth level reaches about 950 x 10^9 kilometers which implies a growth of about 50% from 1990 onward. Without the simultaneous fit of the cycle the sigmoid curve is closer to the observed data and its saturation level becomes much lower, allowing only a growth of about 15%. Not only has such a small amount of further growth less face validity, the additional cycle improved the fit significantly (F-test on residual variance yields $p < 0.01$).

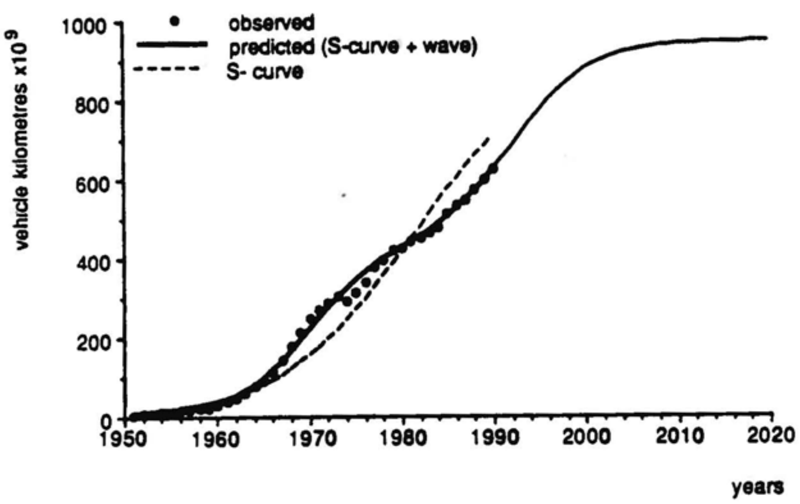

Figure 7. Prediction of vehicle kilometers in Japan.

Despite the prediction is only a function of time the model with a cycle around logistic growth fits remarkable well, apart from a deviation shortly after 1973 which are the years of the oil crises of 1974. It will be noted that for Japan the steepest increase of the sigmoid curve nearly coincide with the steepest decrease of the cyclic deviations around the sigmoid curve at the end of the seventies. The actual increment of the joint predicted growth curve is the highest around 1970 and 1990. Here we note already that if fatalities are foremost a function of these increments, as it is conjectured by our integrated model, one would expect the highest numbers of fatalities around these years and relative lower numbers before, between and after these periods.

Figure 8 gives the analysis for the fatality rate in Japan over the same observation period. Again the observed rates are given (dots) along with the fitted prediction curve (solid line) and the underlying exponential decreasing curve (intermitted line) which is modified by a proportional cyclic influence. The proportional effect of cyclic deviations means that small cyclic deviations at low values compare to large cyclic deviations at high values. The cyclic modification improves the fit significantly with respect to a simple exponential curve.

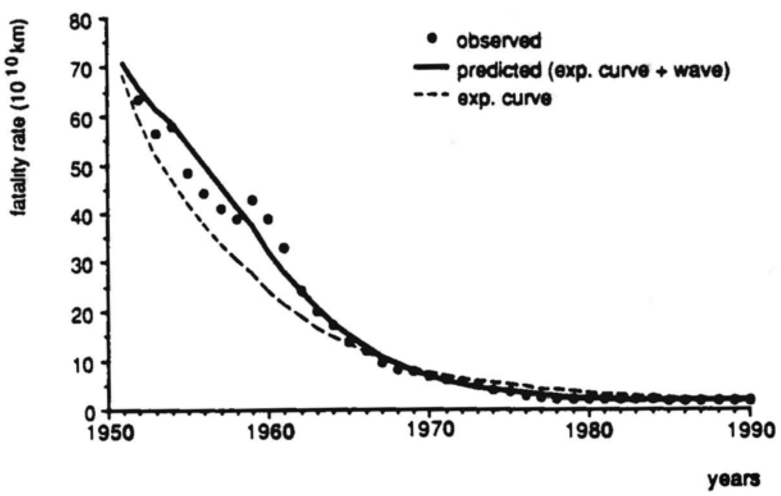

Figure 8. Analysis of the fatality rate in Japan.

It will be noted that a fitted exponentional curve without cycle will lay closer to the observed values than the simultaneous fitted exponential curve. The fitted cycle for deviations around the exponential curve is proportional to the derivative of the cyclic curve around the sigmoid growth curve and is, therefore, shifted by a quarter of the period. This means that relative cyclic increases or decreases of the fatality rate follow the cycle of the vehicle kilometers with a 9 year time-lag. Therefore, a partial delayed overlap of relative increments or decrements in growth of vehicle kilometers and in fatality rate is present. This can have disastrous effects on the number of fatalities in predicted periods of partial overlapping relative higher vehicle kilometers and relative higher fatality rates.

Figure 9 shows the results for the predicted fatalities in Japan. This prediction is based on the product of the predicted curve of Figure 7 and observed (and after 1990 predicted) values of Figure 8. Due to cyclic deviations in both underlying curves (Figures 7 and 8) and their locations in time with respect to the steepest increase of the sigmoid curve, the Japanese results show two peaks in the number of fatalities.

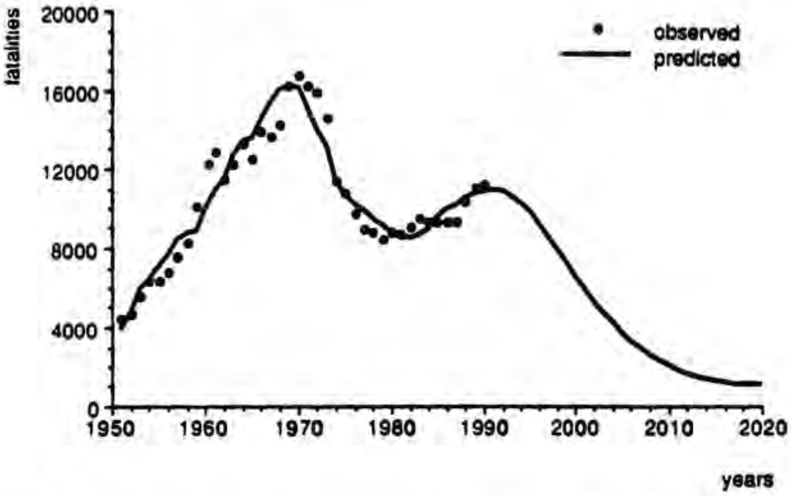

Figure 9. Observed and predicted fatalities in Japan.

The predictions from 1951 to 1990 fits remarkable good. Due to the saturating growth in vehicle kilometers and due to prediction of the fatality rate which virtually reduces to zero if time proceeds infinitely, the long term prediction of fatalities is very optimistic.

3.2. United States of America

Figures 2 to 4 pictured the analysis for the USA from 1923/25 onwards by an analysis without a cycle around the sigmoid growth curve and the exponentially decreasing fatality rate. Although the downward trend in the prediction of figure 4 may be correct, its actual prospective value is doubtful in view of marked deviations observed for the past prediction period. An analysis by the integrated model with a cycle shows that the apparent post war cycle is disrupted by World War II and does not have the same location (and perhaps phase) before that war. If we only analyze the post war period by our integrated model with cyclic deviations around monotonic curves the precision of the predicted values of mileage and fatalities enhances markedly. This is shown in the Figures 10 and 11, where the two-year mean values of mileage and fatalities from 1949 onward are given.

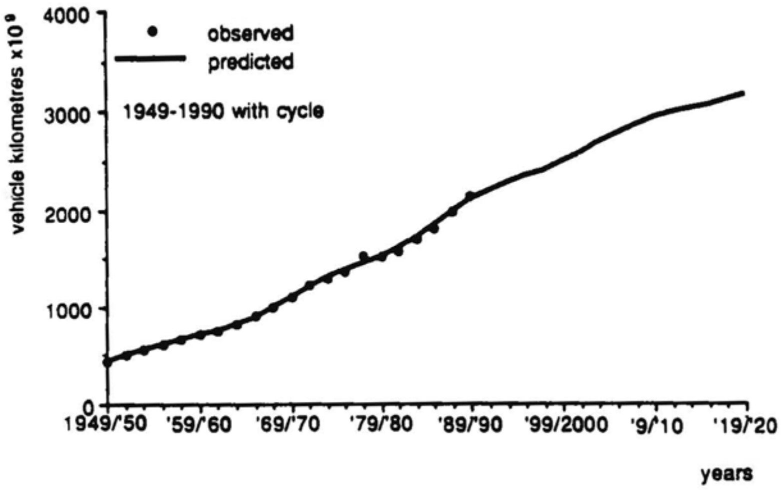

Figure 10. Mobility analysis in the USA from 1949 to 1990.

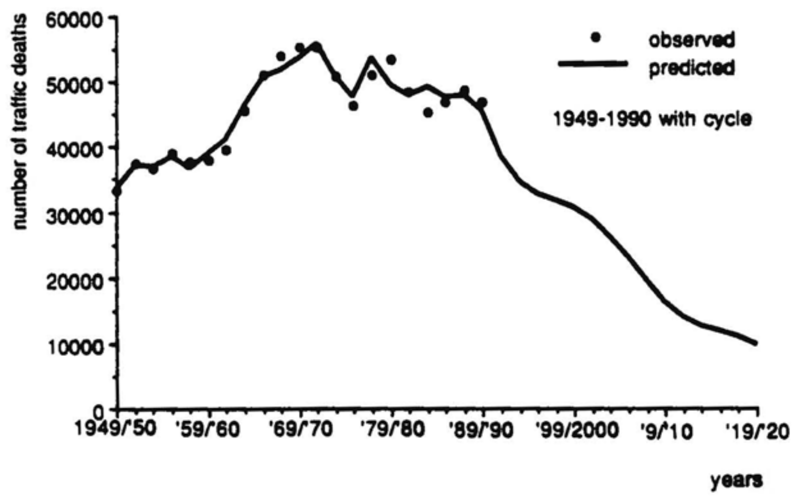

Figure 11. Observed and predicted fatalities in the USA from 1949 to 1990.

The retrospective prediction error for yearly mileage for the USA remains within the 5% range and for fatalities per year within the range of 8%. The effects of the cycles with a period of 20 years in the USA are also very well visible in the forecast up to the year 2020.

3.3. Germany (west)

Figures 12 and 13 give the results for motorized kilometers and fatalities in former western Germany as two-years mean values from 1953/54 on ward to 1989/90 retrospectively and prospectively predicted to 2019/20, obtained by the same integrated model with cycles around monotonic trends.

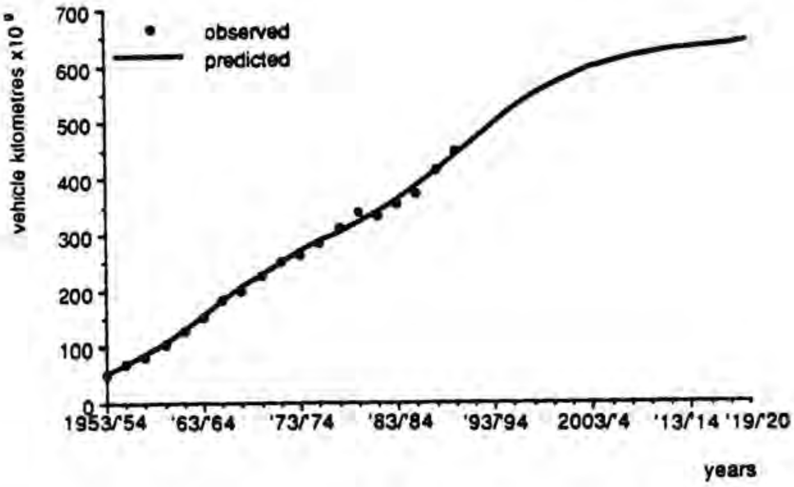

Figure 12. Mobility analysis for Germany (west)

The saturation level for (West) Germany is not very well defined by the fit of its own growth development, but due to the theoretical relation with fatalities it can be taken to be about 675×10^9 km. Higher estimates, however, are not significant worse. There is a significant cyclical deviation from the sigmoid growth trend with a period of 38 years. The oil crisis of 1974 follows shortly after a positive cycle deviation and just precedes the steepest increase of the sigmoid trend, which seems to be a common aspect for the results of most other motorized countries. The oil crisis of 1974 seems, therefore, more an induced reaction to demand for oil than an unexpected disturbing factor. In contrast to Japan, the maximum increment of the underlying sigmoid growth does not coincides with a maximum decrease of the cyclic influence. Therefore and because of smaller cyclic influences than in Japan, the actual development of fatalities can not have a second peak in (West) Germany.

The retrospective and prospective prediction of fatalities (the solid lines of Figure 13) are again obtained from the observed and predicted vehicle kilometers and the fitted risk adaptation curve. The reduced cycle around the exponential risk curve fits the predicted time lag of a quarter of the cycle period compared to cycle around the sigmoid growth curve. The cycle around the exponential fatality rate contribute significantly to the fit of the estimated risk curve. The fit is only so optimal if the predicted fatality rate reduces infinitely to a virtual zero level. Hence fatalities will also reduce to virtually zero in the end.

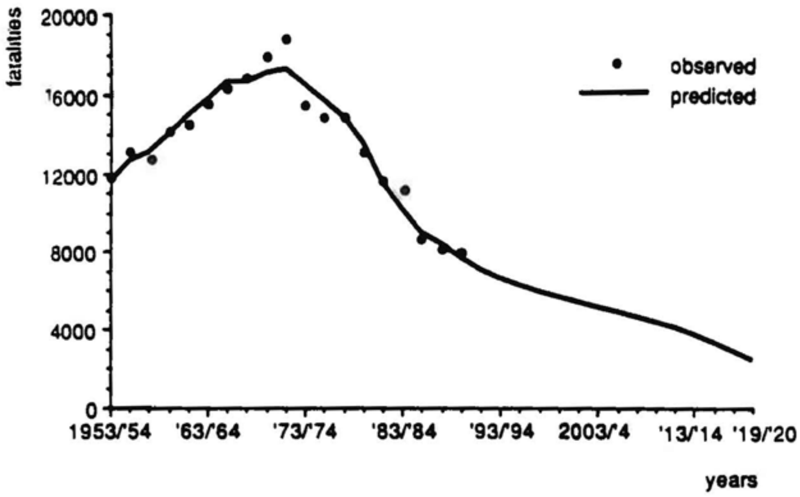

Figure 13. Observed and predicted fatalities in (West) Germany.

The presented analyses for these three industrialized countries illustrate that mobility growth and traffic risk adaptation and the resulting fatalities can be modeled by processes which only depend on time, while the effects of relatively increased and unadapted growth can be disastrous for the development of the fatalities. So it has been in all industrialized countries with a peak in road fatalities in the beginning of the seventies and so it will be again for Japan (and Israël, see Koornstra, 1991) in the nineties. The non-decreasing (or even increasing) number fatalities in the period before or around 1990 in the presented countries is, according to our analysis, the result of the relative increased growth of mobility in the recent past which also causes, according to our analysis, a temporary delayed reduction of the fatality rate. As shown in the prospective predictions, this is not a sign of permanent worsening of the safety in the road traffic of the future. On the contrary, our long term predictions are optimistic due to the best fitting limit value of zero for the fatality rate (time proceeding to infinity). Since the independent variable is time which is a perfectly predictable variable and because the past period of 40 years or more in many countries is fairly accurately predicted by our time-based models it probably is a reliable prediction method for the future development of mobility and road safety in the next decade. Moreover, the integrated model is rooted in the general theory of technological evolutions (Koornstra 1991a; 1991b, 1992) and, therefore, these models also provide a scientific quite acceptable basis for its predictive results. This is more than any other model based on ad hoc independent variables (which themselves must be also predicted for the prediction of safety in the future), such as socio-economic indicators for the prediction of fatalities (Partyka, 1991), can claim.

4. FORECASTS FOR EAST EUROPEAN COUNTRIES

The above theory and models may be as well applied to the development of motorization and safety in East European countries. The development in Eastern Europe can be seen as a technological evolution of motorization which up to 1989/90 has been retarded by socio-economic constraints and political system conditions. On top of this retardation a possibly present cyclic wave around starting developments may express the stagnation of further growth for the worsened situation after the seventies by a socio-economic repression in the last decade. Socio-political constraints in Eastern Europe are released some time ago and it can be assumed that the economic repression will turn into an upsurge in this decade. A quantitative analysis may show whether these expectations are reflected in the growth of motorized mobility up to now and if so it may be a basis for model prediction of the future. If such an analysis also confirms the close relation between mobility growth and risk adaptation, than the development of the fatality rate in the future is also sustained by theory.
In another paper we suggested developments of mobility and safety for Eastern European countries on the basis of the general trends only (Oppe & Koornstra, 1992). Here we will give an alternative and more detailed description, using the general trends as well as the cyclic deviations. The following analyses are restricted to the countries of Hungary, Poland and the Czech and Slovak Republic(s). For these countries we do not have a complete set of annual motor vehicle kilometers, but the number of annually registered passenger cars from the sixties onward can be used instead. Generally the development of the number of passenger cars is strongly correlated with the total motor vehicle kilometers. This can be also deduced from the fact that in the begin we have a relative small number of cars with a relative low mean kilometrage driven (actually about 7000 km per year) and a relative large share of kilometrage for busses, motorcycles and trucks, while in the end we have a large number of passenger cars with a relative larger mean kilometrage and a much smaller share of total kilometrage for busses, motorcycles and trucks.

A period of data of 30 years or less and the particular circumstances in the East European countries do not allow that we determine the estimation of the saturation level of motorization from the development of the given data over that period since the sixties. We, therefore, assume that the saturation levels of motorization for these countries are the same as for (West) Germany. This means we, given the predicted saturation for (West) Germany which is 47% higher (see Figure 12) than the present level of motorization (about 2 persons per car), we fix the saturation level of motorization on 1.4 person per car. The resulting saturation levels for the number of cars for a fixed number of inhabitants per country are given in Table 1.

Country	Inhabitants x1000 in '90	Cars '90 x1000	Ratio pers./cars in '90	future	Saturation level
Germany (W)	62.679	30.684	2.04	1.4	44.800
Czech/Slovak	15.519	3.122	4.97	1.4	11.100
Poland	38.038	5.261	7.32	1.4	27.200
Hungary	10.375	1.945	5.34	1.4	7.400

Table 1. Inhabitants, motorization and resulting saturation level.

With these tentatively fixed parameters the other parameters are fitted to the data of passenger cars and fatalities for the three mentioned East European countries. In Figures 14 to 19 the predictive results of the analysis are given in the same way as before, but now for mobility growth by passenger cars and implicitly by fatality rate per passenger car.

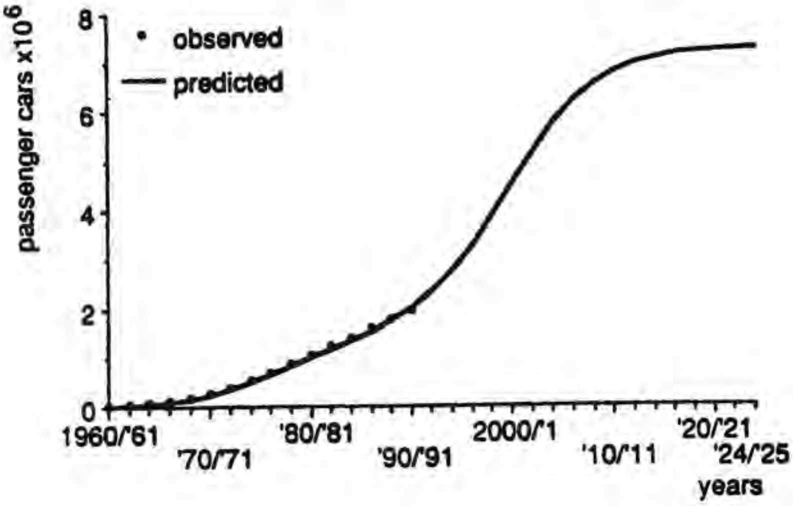

Figure 14. Forecast analysis of motorization in Hungary.

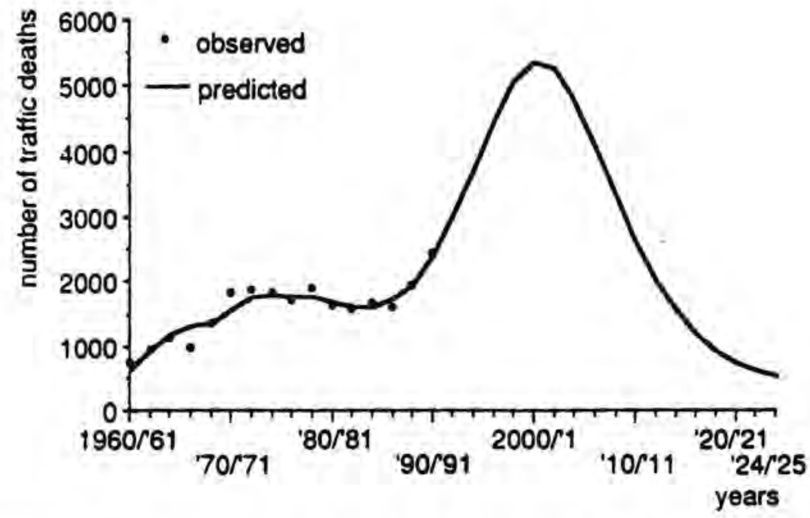

Figure 15. Forecast analysis of fatalities in Hungary.

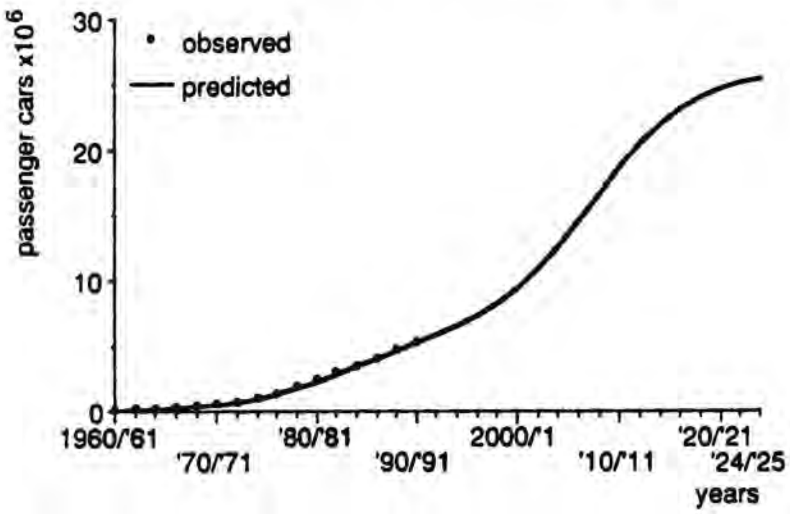

Figure 16. Forecast analysis of motorization in Poland.

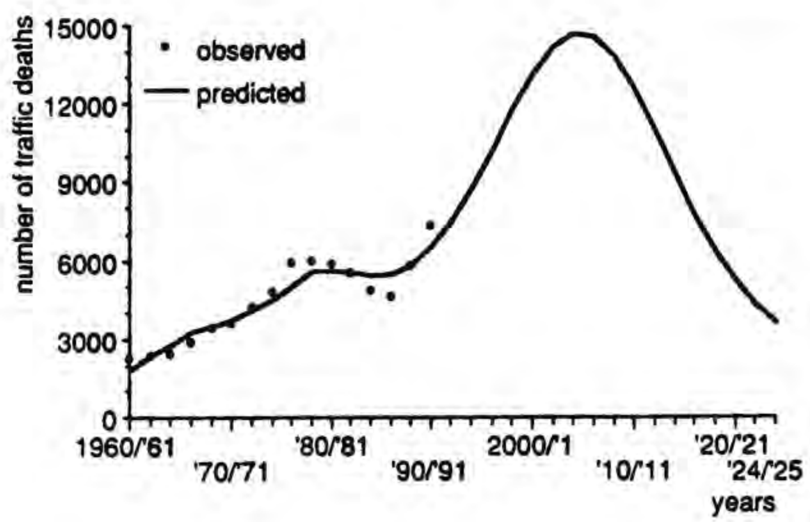

Figure 17. Forecast analysis of fatalities in Poland.

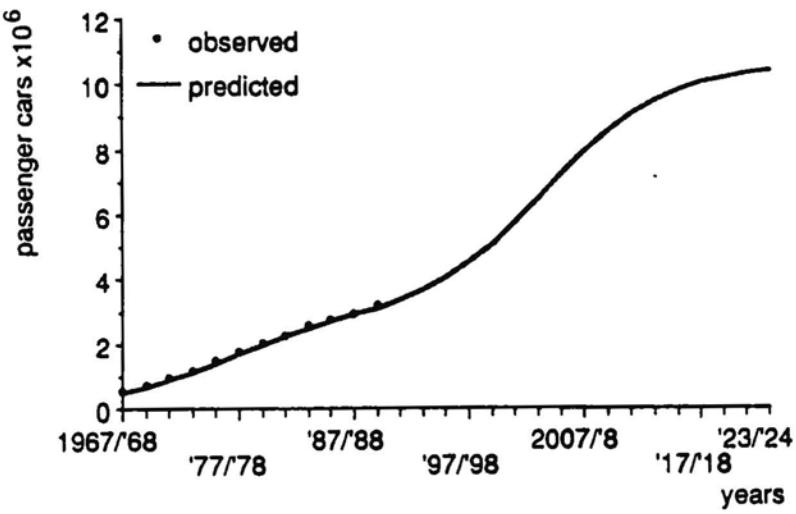

Figure 18. Forecast analysis of motorization in Czech & Slovak Republic(s)

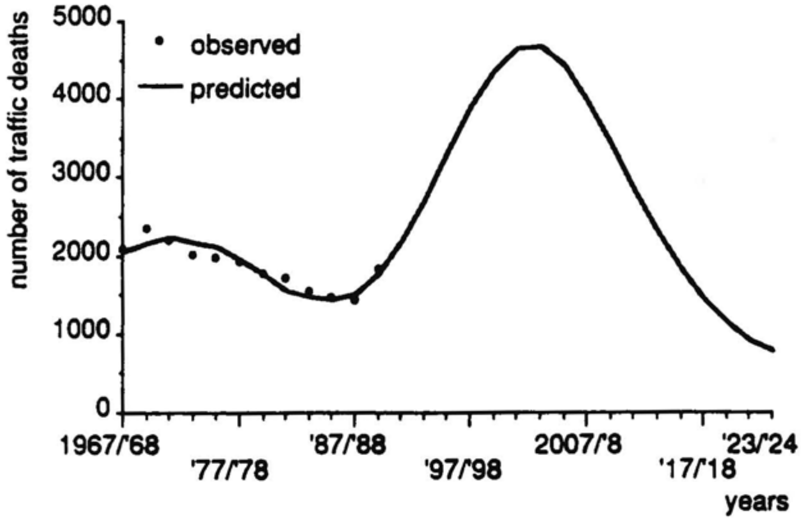

Figure 19. Forecast analysis of fatalities in Czech & Slovak Republic(s)

Despite a priori fixed saturation levels the retrospective prediction of the annual number of cars is quite satisfactory. The same holds for the fit to the observed fatalities over the 31 years period for Hungary and Poland, although less for Poland, and the 24 years period for the Czech and Slovak Republic(s). The optimal cycle period for these countries is about 40 years, a period comparable to the ones of Germany (west) and Japan. The most encouraging fact for the possible validity of the predictions, however, is that also the respective slope parameters for growth of motorization and fatality rate (per car in this case) also tend two show the theoretically expected ratio of a half, just as was shown for the industrialized countries in Figure 5. The values of the respective slope parameters are shown in Table 2.

Country	Volume parameter	Risk parameter
Czech/Slovak	0.0981	0.0511
Poland	0.1174	0.0596
Hungary	0.1432	0.0685

Table 2. Comparison between slope parameters of volume and rate.

The satisfactory retrospective fit and the above table in relation to Figure 5 can be seen as evidence for the tentative validity of the predictions. The prediction of the safety development is far from reassuring. The industrialized countries have experienced a tremendous increase in fatalities between the second half of the fifties and the onset of the seventies. Just in the same way the East European countries have to envisage a comparable increase in fatalities between to day and the next ten years. Their development can be regarded to be retarded by about 30 years with respect to North-West Europe, but in the coming decades these countries catch up the backlash in motorization with the adverse consequences for road safety. The total number of fatalities for the sum of the three analyzed countries is predicted to increase from 12.000 nowadays per year to about 25.000 per year at its maximum around the year 2003. This prediction may even be somewhat optimistic, because the marked increases of fatalities in 1990 are already underestimated. On the other hand, one should realize that these forecasts are based on restricted empirical evidence and on a hypothetically assumed saturation level of motorization. After the first decade of the next century the annual number of fatalities is predicted to decrease gradually to about 5000 in the year 2025, but such long term predictions must be taken as far from reliable. However, from the evolutionary theory it follows, if the cyclic influence does not create a second peak, that a gradual reduction must be observed after the increase to a certain maximum.

One may wonder whether it is possible to prevent the increase of fatalities by safety policies. From our evolutionary theory (Koornstra, 1991a; 1991b, 1992) improved safety is the result of better adapted replacements of sequences of subsystems or elements in the traffic system. Whether these renewal processes concern infrastructure, cars, laws, or generations of better educated road users, all these processes asks for investments and time. Therefore, it is doubted whether the increase in fatalities can be actually reduced in the next ten years, given the economic circumstances in Eastern Europe. Specific actions which are beneficial may be taken, based on the joint experiences of West and East European countries with regard to effective measures, but is not the topic of this study. This study stresses the importance of international comparisons and validations of theoretical relation between traffic and safety developments on the basis of comparable defined data for traffic and safety. International cross validations increases the validity of forecasts for policies on national and international levels. It is hoped that the forecasts for Eastern Europe motivate decision makers to provide possibilities for research cooperation between East and West Europe in order to establish more effective policies, which surely ask also for joint financial support for the necessary actions to be taken.

REFERENCES

- Broughton, J. (1988). Predictive models for road accident fatalities. Traff. Eng. & Control, 29: 296-300.
- Chatfield, B.V. (1987). System-wide safety improvements: an approach to safety consistency. Transp. Res. Board. R-132, Washington.
- Haight, F.A. (1988). A method for comparing and forecasting annual traffic death totals: The United States and Japan. Int. Conf. Proc. "Road Safety in Europe". Gothenborg. VTI, Linkoping.
- Koornstra, M.J. (1987). Ridendo dicere verum. R-87-35, SWOV, Leidschendam.
- Koornstra, M.J. (1988). Development of road safety in some European Countries and the USA. Int. Conf. Proc. "Road Safety in Europe". Gothenborg. VTI, Linkoping. (R-88-33. SWOV, Leidschendam.)
- Koornstra, M.J. (1991a). Evolution of mobility and road safety. In: Hakkert, A.S. & Katz, A. (Eds.) Proc. 2nd Int. Conf. "New ways for improved road safety and quality of life. Tel Aviv. TRI, Technion, Haifa.
- Koornstra, M.J. (1991b). Mobility and road safety. Paper presented at the 3th ISRT Round Table "The Future of Mobility", Toulouse (to be published in IATSS Research).
- Koornstra, M.J. (1992). The evolution of road safety and mobility. Paper presented at the 6th World Conference on Transport Research. Lyon. (to be published, available as draft report from SWOV).
- Oppe, S., Koornstra, M.J. & Roszbach, R. (1988). Macroscopic models for traffic and traffic safety. In: Traffic safety theory and research methods. Session 5. SWOV, Leidschendam.

- Oppe, S. (1989). Macroscopic models for traffic and traffic safety. Accid. Anal. & Prev. 21: 225-232.

- Oppe, S. & Koornstra, M.J. (1990). A mathematical theory for related developments of road traffic and safety. In: Koshi, M. (Ed.). Transportation and traffic theory. 113-133. Elsevier, New York.

- Oppe, S. (1991a). Development of traffic and traffic safety in six developed countries. Accid. Anal. & Prev. 23: 401-412.

- Oppe, S. (1991b). Developments of traffic and traffic safety: Global trends and incidental fluctuations. Accid. Anal. & Prev. 23: 413-422.

- Oppe, S. & Koornstra, J. (1992). Traffic and Traffic Safety in Central and Eastern European Countries. 17th International Study Week on Traffic Engineering and Safety, Warsaw.

- Partyka, S.C. (1991). Simple models of fatality trends revisited seven years later. Accid. Anal. & Prev. 23: 423-430.

- Teilhard de Chardin, P. (1948). Le phénoméne humain. Editions de Sueil, Paris.