

# Sustainable safe walking: the need for a pedestrian safety policy in P.R. China

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## Abstract

The paper analyses the safety situation of vulnerable road users in China, with a focus on pedestrians. A major side-effect of the strong economic development in China in recent years is a high number of traffic accidents. It is remarkable that pedestrian fatalities count for around 26% of total road fatalities, and pedestrian injuries for around 18% of total road injuries. In this study, the possible causes of accidents that involve pedestrians are explored, an analysis is provided of the reasons why pedestrian safety is not a topic of high priority in China. Although traffic legislation in China has improved since 2004, until now there is no quantitative national road safety policy goal for improving pedestrian safety, and there is no nation-wide initiative to raise road user awareness of traffic safety, to improve the road infrastructure from a safety perspective, and to implement in-vehicle driving assistance systems to protect pedestrians. Finally, some recommendations are provided for new initiatives and policy changes in China.

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## Introduction

Road traffic accidents are perceived as a major societal problem in P.R. China. With the economy booming, the number of vehicles has been increasing more than 17% per year since 2005. As part of this, the increase of the number of passenger cars has even been more than 22% per year, and the total number of passenger cars has increased to nearly 32 million in 2007 [Dong, 2008]. One of the side-effects of this rapid development is a high number of traffic accidents (see Figure 1). The Chinese authorities have taken various countermeasures to improve traffic safety, based on legislation, regulation, education and changes in road infrastructure. According to the official data, the accident severity has been decreasing since 2003. For instance in 2007 the numbers of fatalities and injuries are 81,649 and 380,442 respectively, and the number of fatalities per billion motor vehicle kilometres is around 71 (which is considerably higher than that in the developed countries). Note that the number of fatalities per million inhabitants in China is very low, due to the fact that a large part of the population does not have cars. Although the number of accidents has been decreasing sharply in recent years, the toll of traffic accidents remains unacceptably high.

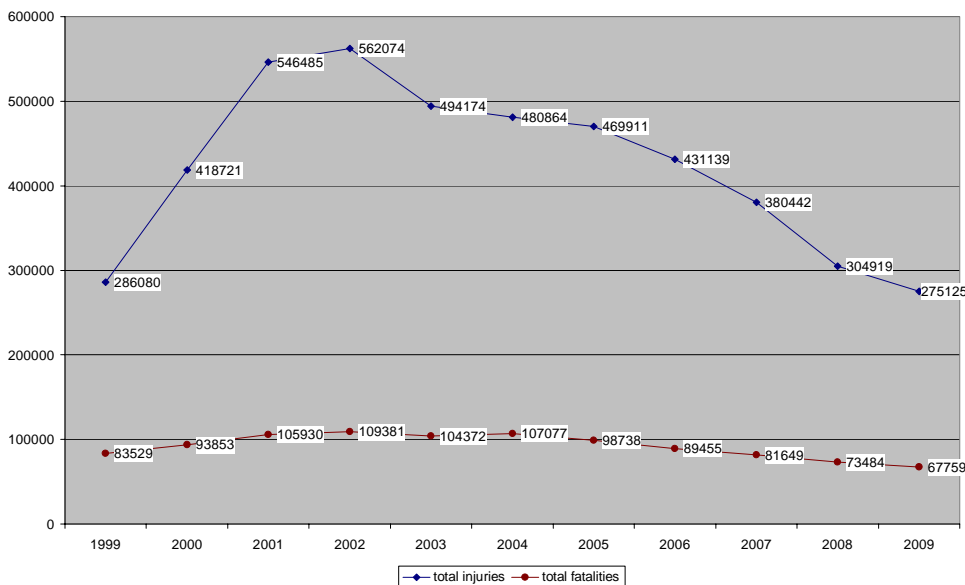


Figure 1 - Road traffic fatalities (bottom) and injuries (upper) in 1998-2009, P.R. China (Source: National Bureau of Statistics of China, 2010)

It is remarkable that pedestrian fatalities count for around 26% of total road fatalities, and pedestrian injuries for around 18% of total road injuries, although various countermeasures to improve traffic safety have been taken in the past years. China is a developing country. The traffic and transport situation is quite different from that in other countries, and as a consequence road accidents may have different causes. Traffic safety data, especially concerning the exposure of pedestrians to the accidents risk is rather incomplete. In addition, the policy decision process in China is different from that in western countries. In view of these considerations, the following three research questions are formulated:

1. What are the possible causes of accidents that involve pedestrians?

2. Why pedestrian safety is not, but needs to become a topic of high priority in China?

3. How to develop and implement new initiatives that could bring about policy change?

To answer these questions, the causes of pedestrian involved accidents in China need to be investigated, the trends of pedestrian safety need to be quantified, based on which scenarios could be made in order to support the initiatives for pedestrian safety in China.

In the following sections, the possible causes of accidents that involve pedestrians are explored, an analysis is provided of the reasons why pedestrian safety is not a topic of high priority in China. Finally, some recommendations are provided for new initiatives and policy changes in China, and conclusions are drawn.

## Pedestrian safety: an crucial issue in China

### Potential reasons of accidents that involve pedestrians

Although the amount of vehicles, especially passenger cars, is increasing rapidly in China, walking and cycling are still the main travel modes in urban and rural areas. As in The Netherlands, most people in China have a bicycle. Traffic conflicts (i.e. potentially unsafe events that require an evasive action or manoeuvre) that involve pedestrians are not limited to conflicts between pedestrians and motor vehicles, but also include conflicts between pedestrians, cyclists and moped users mutually. In general, the total number of accidents that involve pedestrians has been decreasing since 2005, however, the ratio of fatalities and injuries caused by accidents involving pedestrians is still remarkably high (see Table 1)

Table 1 - Pedestrian fatalities and injuries in China (1999-2009)

Year	Fatalities (total)	Pedestrian fatalities	%	Injuries (total)	Pedestrian injuries	%
1999	83,529	21,686	25.96	286,080	37,554	13.13
2000	93,853	24,580	26.19	418,721	55,104	13.16
2001	105,930	28,274	26.69	546,485	75,137	13.75
2002	109,381	27,575	25.21	562,074	76,779	13.66
2003	104,372	25,673	24.60	494,174	68,040	13.77
2004	107,077	26,741	24.97	480,864	76,431	15.89
2005	98,738	24,451	24.76	469,911	83,491	17.77
2006	89,455	23,285	26.03	431,139	82,391	19.11
2007	81,649	21,106	25.85	380,442	70,838	18.62
2008	73,484	18,913	25.74	304,919	56,303	18.46
2009	67,759	16,683	24.62	275,125	47,594	17.30

(Source: MPS-DTM, 2010)

From a statistics point of view, three basic traffic safety dimensions can be identified: (road traffic) exposure, accident risk and accident consequence [Rumar, 1988; Nilsson, 2004]. Pedestrian exposure to the risk of road accidents is an important subject, which has been studied in previous research (see e.g. [Keall, 1995; Cameron, 1982; Qin & Ivan, 2001, Molino, et al., 2009]). Due to limited availability of data at this stage, pedestrian exposure to accident risk in China cannot be quantified. Nevertheless, as China is a large country, and as the development in different regions is rather unbalanced, the study of pedestrian exposure to risk in China would only make sense at a local level. In this study the analysis concerning research questions 1 and 2, is mainly based on available (but very limited) data, literature review, expert knowledge and interviews.

Concerning the remarkably high ratio of pedestrian involved accidents in China, the following possible explanatory factors are proposed based on logical reasoning:

1. substantial yearly increase rates of exposure of pedestrians, vehicles and other road users;
2. large number of conflicts between pedestrians, vehicles and other road users due to poor infrastructure design;

3. Chinese road users often behave against traffic regulations and legislation, and priority rules are either missing, or often not well obeyed;
4. pedestrians, as the weakest road users (i.e. with lowest mass, without protection), suffer from the consequence of the accident most severely;
5. some (risk) factors, such as human behaviour are still insufficiently understood and difficult to control or influence;
6. countermeasures for improving pedestrian safety are not implemented sufficiently and comprehensively from the perspective of legislation and traffic regulation, measures directly acting on driving behaviour, road infrastructure related measures and vehicle related measures.

### Need for a topic of high priority in China

Traffic legislation in China has improved since 2004, and the total accident frequency and severity are decreasing (see Figure 1). However, the aforementioned analysis shows that the situation of pedestrian safety in China is serious. A research study of the level of service at signalised intersections in 2009 [Bian, et al, 2009] found that the rate of traffic violations by pedestrians, as well as affecting pedestrians in China is very high; the priority of pedestrians is often ignored by drivers of motor vehicles, mopeds and bicycles; and there is no effective policy or law restricting traffic-violating behaviour affecting pedestrians and ensuring their legal rights. The analysis of potential reasons of accidents that involve pedestrians helps us to further investigate and identify which countermeasures are needed for improving pedestrian safety, as a basis for supporting a fundamental and effective change in policy focusing on prioritising pedestrian safety. At the national level, there is a need for:

1. quantitative national road safety policy goal for improving pedestrian safety;
2. nation-wide initiative to raise road user awareness of traffic safety;
3. nation-wide initiative to implement comprehensive countermeasures to protect pedestrians.

### Seeking new initiatives and policy changes

For studying the traffic safety system, two concepts should be distinguished: traffic safety in terms of historical statistics ( $TS_S$ ) and Traffic safety in terms of probability ( $TS_P$ ).  $TS_S$  is the resultant of two components, accident frequency ( $F$ ) and accident severity ( $S$ ), which can be denoted as  $TS_S = f_s(F, S)$ .  $TS_P$  can be described as the resultant of accident risk ( $R$ ) and accident consequence ( $C$ ), which can be denoted as  $TS_P = f_p(R, C)$ . Accident risk and accident consequence are defined as *theoretical* stochastic variables, while the terms accident frequency and accident severity are defined as the *actual* outcomes, where obviously frequency is related to risk, and severity to consequence. Note that in some publications these terms are defined in a slightly different way (e.g. [IEC. 2000; Kaplan,, 1981; Bald,, 1991]). Distinguishing reality ( $TS_S$ ) and theory ( $TS_P$ ) may help us to reconsider road traffic safety policies. Efforts can be put to reduce *theoretical* accident risk to (nearly) zero. But *real* accident can not be (permanently) reduced to zero if there are still unknowns factors and/or uncontrollable parameters in the traffic safety system. The  $TS_S$  approach aims to identify locations with higher accident frequency and/or higher accident severity. This has been implementing in China at the local level. The  $TS_P$  approach focuses on implementation of a range of sustainable safety policy measures at the national level for all road networks, such as has been done in The Netherlands [Koornstra, et al., 1992; CROW, 1997]. The purpose of both approaches is to improve traffic safety effectively, and to take costs into account.

A better understanding of the traffic safety system may help to set more reasonable national policy goals and to more efficiently and effectively formulate and implement related policies. A relevant question in this respect is how to identify the pattern of traffic safety improvement in China. To deal with this problem, a proper forecasting method needs to be selected for a sufficiently reliable and valid result.

# Forecasting pedestrian safety improvement

## Forecasting techniques

Prominent forecasting techniques are time-series methods (e.g. exponential smoothing, decomposition and autoregressive / moving average - ARMA), causal forecasting methods (e.g. regression analysis, econometric models, input-output models and simulation modelling), Markov process, grey model, and in addition qualitative methods (e.g. product life-cycle analogy, expert knowledge and Delphi) [Makridakis & Wheelwright, 1978; Deng, 1989].

The underlying premise for every quantitative forecasting method (and for some qualitative methods) is that the pattern of the past will continue into the future (i.e. the assumption of constancy). In grey model it is assumed that the pattern of the data series to be processed is exponential, or can be transformed to an exponential pattern by some form of pre-processing. Grey model aims to describe this exponential pattern (called "dynamic systems behaviour") between the discrete elements in the series. The fundamental schema behind the grey model is to deal with the causality between the different elements of the data set, given or represented as an exponential discrete series. The grey model provides a tool for dynamic modelling of discrete series based on few data (a minimum of four data values is needed). This is a unique and distinguished characteristic of the model. Various uncertainties exist in the traffic safety system. Noisy factors that influence road traffic safety are, e.g. change of legislation, regulation, behaviour, quality of vehicles, road design, and other random and unknown factors. Using more historical data covering a long period has the potential to increase modelling noise, therefore, to reduce the accuracy of the forecasting result. For this reason, the grey model was selected for studying pedestrian safety in China.

## Grey system and grey model GM(1,1)

Grey model is one of the methods of grey system. Grey system theory is based on grey uncertainty, which was initially proposed by J. Deng in 1982 [Deng, 1982]. The purport of the grey model is to deal with the problem of system modelling with incomplete information by rebuilding the dynamic process. The grey model is denoted as GM( $n, h$ ), which is a  $n$ -th order pseudodifferential equation of  $h$  variables. GM(1,1), a first order ordinary pseudodifferential equation, is the basic dynamic model, and especially used for forecasting. This advanced numerical model has been applied for more than two decades, and its performance in modelling and forecasting, e.g. for agriculture, environment, earthquakes and stock-price indices, was widely acknowledged (see e.g. [Yu, et al., 2006; Zhang & Luo, 1985; Zhou & Deng, 1989; Zhou, et al., 2006; Cheng & Chang, 2001; Chang, et al., 2004; Lian, 2005; El-Fouly, 2006]).

## Essential principle and algorithm of GM(1,1)

The GM(1,1) model can be seen as a coupling of a pseudodifferential equation and a simple regression [Guo & Guo, 2008]. The original discrete positive data series in GM(1,1) is represented as:

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(N)) \quad (1)$$

The operation to transform this series to satisfy the condition of an exponential pattern is named the *accumulated generating operation* (AGO). It is in essence the creation of the series of partial sums of the original series. The first-order accumulated generating series is:

$$X^{(1)} = (x^{(1)}(1), x^{(1)}(2), \dots, x^{(1)}(N)) \quad (2)$$

where  $x^{(1)}(k) = \sum_{i=1}^k x^{(0)}(i)$ ,  $k = 1, 2, 3 \dots, N$ .

The AGO can be carried out one time or several times until the series satisfies the condition that all

quotients of successive terms  $\alpha(k)$  are close to a constant  $c$  (proof see [Deng, 2002]), where  $\alpha(k) = x(k) / x(k+1)$ , and  $c \in [e^{2/(N+1)}, e^{2/(N-1)}]$ . By this data pre-processing randomness and noise of the original data series are decreased, and (exponential) regularity and smoothness are increased [Deng, 1989]. For a discussion of the fundamental conditions concerning the requirements for an exponential pattern for improving the reliability of the grey model, see also [Shen, 2001; Chen, et al., 1999].

Grey model could be taken as an efficient approximation for extracting system dynamic information [Guo, 2005]. The pseudodifferential equation of GM(1,1) to describe the discrete series, Equation (1), is defined as

$$x^{(0)}(k) + az^{(1)}(k) = u \quad (3)$$

where  $a$  denotes the exponential developing coefficient with domain  $a \in [-2, 2]$ , and parameter  $u$  is the grey actuating variable, which reflects the variation of data.

In Equation (3),  $z^{(1)}(k) = \alpha x^{(1)}(k) + (1 - \alpha) x^{(1)}(k - 1)$ , where  $0 \leq \alpha \leq 1$ . The choice of the parameter  $\alpha$  depends on the criterion for optimisation of the information in view of its limited availability. According to the current status of research (see e.g. [Hsu, et al., 2006]) there is no general rule to establish a value for this adjustment parameter, and it can be taken as 0.5, which is named the *mean value generating operation* (MGO) [Deng, 1989].

$$z^{(1)}(k) = \frac{1}{2} (x^{(1)}(k-1) + x^{(1)}(k)) \quad (4)$$

Note that the pseudodifferential Equation (3) is analogous to the conventional differential equation [Guo, 2005; Guo, et al., 2006]:  $dx^{(1)}(t) / dt + ax^{(1)}(t) = u$ . An assumption is made for dealing with the discrete data series:  $dx^{(1)}(t) / dt$  is deformed into  $x^{(1)}(k) - x^{(1)}(k - 1)$ . The *inverse accumulated generating operation* (IAGO) is defined as:  $x^{(0)}(k) = x^{(1)}(k) - x^{(1)}(k - 1)$ . Therefore, the approximation is generated as:  $dx^{(1)}(t) / dt \approx x^{(1)}(k) - x^{(1)}(k - 1) = x^{(0)}(k)$ , and  $x^{(1)}(t) \approx z^{(1)}(k)$ .

The pseudodifferential equation can be expressed in matrix form as:

$$\mathbf{Y}_N = \mathbf{B}\Theta \quad (5)$$

$$\text{where } \mathbf{Y}_N = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(N) \end{bmatrix}, \mathbf{B} = \begin{bmatrix} -z^{(1)}(2) & 1 \\ -z^{(1)}(3) & 1 \\ \vdots & \vdots \\ -z^{(1)}(N) & 1 \end{bmatrix}, \Theta = \begin{bmatrix} a \\ u \end{bmatrix}$$

The optimised solution of the parameters  $a$  and  $u$  can be determined by the classical least-square method as:

$$\Theta = \begin{bmatrix} a \\ u \end{bmatrix} = (\mathbf{B}^T \mathbf{B})^{-1} \mathbf{B}^T \mathbf{Y} \quad (6)$$

The solution (i.e. the discrete time response series) of the pseudodifferential equation GM (1,1) is given by

$$\hat{x}^{(1)}(k+1) = \left( x^{(0)}(1) - \frac{u}{a} \right) e^{-ak} + \frac{u}{a} \quad (7)$$

where  $x^{(0)}(1) = x^{(1)}(1)$ ,  $\hat{x}^{(1)}(k+1)$  denotes the prediction series.

## Modelling and forecasting process of GM(1,1)

### Data pre-processing

Apply the AGO, if necessary repeatedly until the series satisfies the exponential requirement, to get the first-order accumulated generating series.

### *Grey modelling by GM(1,1)*

The optimised solution of the parameters  $a$ ,  $u$  is determined by Equation (6), and the solution of  $\hat{x}^{(1)}$  at any time is obtained as Equation (7). From the estimated (or simulated) values  $\hat{x}^{(1)} = \hat{x}^{(1)}(2), \hat{x}^{(1)}(3), \dots, \hat{x}^{(1)}(N)$  the original series  $x^{(0)}$  is restored by IAGO (inverse AGO):  $\hat{x}^{(0)}(1) = x^{(0)}(1)$ ,  $\hat{x}^{(0)}(k) = \hat{x}^{(1)}(k) - \hat{x}^{(1)}(k-1)$ ,  $k = 1, 2, 3, \dots, N$ , which can also be expressed as  $\hat{x}^{(0)}(k+1) = (1 - e^a) \left( x^{(0)}(1) - \frac{u}{a} \right) e^{-ak}$ .

### *Model accuracy verification*

Grey system model addresses system dynamics from the point of view of the degree of information availability [Guo, 2005], which contrasts with the view of traditional statistics. Errors can be introduced in two ways: 1) the approximation of a continuous differential equation by a discrete pseudodifferential equation; and 2) the estimation by the least-square method [Hsu, et al., 2006]. Quite some discussions are ongoing about model accuracy analysis (e.g. see [You & Wen, 2000; Wu & Wen, 2001]). The commonly used error analysis methods are residual checking, poster checking (or post-error inspection), rolling checking and envelope residual model. These methods can be applied for analysing errors generated from grey modelling (for detailed procedures see [Wu, et al., 1996]). In this paper the method of residual checking of the error value is used:

$$e(k) = \frac{x^{(0)}(k) - \hat{x}^{(0)}(k)}{x^{(0)}(k)} \times 100\%, \quad k = 1, 2, 3, \dots, N \quad (8)$$

### *Grey forecasting*

By extrapolating the modelled series, the values of  $\hat{x}^{(1)}(N+1), \hat{x}^{(1)}(N+2), \dots, \hat{x}^{(1)}(N+M)$  can be predicted, where  $M$  is the number of steps of the forecast (for discussion see e.g. [Liu & Lin, 2006]). Generally, the smaller  $M$  is, the higher the accuracy of the result. It should be stressed that the forecasting process can be applied, if and only if the result of the grey modelling of the historic data is sufficiently accurate.

## **Applying GM (1,1) for modelling and forecasting pedestrian safety**

### *Modelling fatalities and injuries for the years 2005-2009*

Real data of pedestrian fatalities and injuries in year 2005-2009 are presented in Table 2 (left part). The simulated values, based on modelling of the real data, can be computed. The established time response series resulting from the GM(1,1) analysis for pedestrian fatalities and injuries are respectively:

$$\hat{x}^{(1)}(k+1) = \left( x^{(0)}(1) - \frac{1.1193}{0.1097} \right) e^{-(0.1097 * k)} + \frac{1.1193}{0.1097}, \quad \text{where } k = 0, 1, 2, 3, 4.$$

$$\hat{x}^{(1)}(k+1) = \left( x^{(0)}(1) - \frac{1.2735}{0.1853} \right) e^{-(0.1853 * k)} + \frac{1.2735}{0.1853}, \quad \text{where } k = 0, 1, 2, 3, 4.$$

The modelling results as well as the residual error are also presented in Table 2.

### *Prediction of pedestrian safety for the years 2010-2011*

From the low residual error of the modelling result (average residual errors for simulated data of fatalities and injuries are 0.68% and 1.29% respectively), it may be concluded that it is acceptable to apply the model for forecasting fatality values of years 2010 and 2011, by taking  $k = 5, 6$ . The forecast results are presented in Table 2 (right part). The forecasting results show that if no specific countermeasures for the protection of pedestrians will be implemented consistently, by 2010 the total fatalities and injuries will be reduced to 61,346 and 230,914 respectively, and the fatalities and injuries of pedestrians will be counted as 24.58% and 17.11% of the total fatalities and injuries respectively; by 2011 the total fatalities and injuries will be further reduced, but the

fatalities and injuries of pedestrians will remain at the high level, i.e. 24.19% and 16.64% of the total fatalities and injuries respectively.

Table 2 - Result of modelling and forecasting of pedestrian fatalities and injuries

Year	Grey modelling					Grey forecasting	
	2005	2006	2007	2008	2009	2010	2011
fatalities - real data	24451	23285	21106	18913	16683		
fatalities - simulated by GM(1,1)	24451	23380	20950	18776	16822	15076	13509
fatalities - residual error (%)	0.00	0.41	-0.74	-0.72	0.83		
fatalities - average residual error (2005-2009): 0.68%							
injuries - real data	83491	82391	70838	56303	47594		
injuries - simulated by GM(1,1)	83491	82932	68905	57258	47565	39516	32837
injuries - residual error (%)	0.00	0.66	-2.73	1.70	-0.06		
injuries - average residual error (2005-2009): 1.29%							

## Scenarios of pedestrian safety policy

Based on the forecasting result, policy targets for pedestrian fatality and injury reduction in China can be quantified. We propose the following three scenarios:

- Scenario 1 (S1) is related to the  $TS_S$  (traffic safety in terms of historical statistics) approach. It only targets locations with high accident frequency and/or accident severity by improving infrastructure facilities at the local level.
- Scenario 2 (S2) refers to a combination of  $TS_S$  and  $TS_P$  (traffic safety in terms of probability) approaches. It looks for cost-effective and comprehensive countermeasures, e.g. in terms of improving legislation, regulations, reducing traffic-violating behaviour of road users, improving infrastructure design, and implementing vehicle related measures, including applications of in-vehicle driving assistance systems.
- Scenario 3 (S3) is related to the  $TS_P$  approach. It aims at implementing a large-scale sustainable safety policy at the national level by using all available countermeasures.

The effects of pedestrian safety are estimated and presented in Table 3, based on brainstorm and literature review of relevant projects in other countries (see e.g. [Ellis & Van Houten, 2009; Wegman & Aarts, 2006]).

Table 3 - Scenarios of potential pedestrian fatality and injury reduction compared with year 2009

	fatality reduction by 2015	fatality reduction by 2020	fatality reduction by 2025	injury reduction by 2015	injury reduction by 2020	injury reduction by 2025	Expected costs
S1	20%	30%	40%	25%	35%	45%	low
S2	30%	40%	55%	30%	45%	60%	medium
S3	40%	55%	70%	40%	60%	75%	high

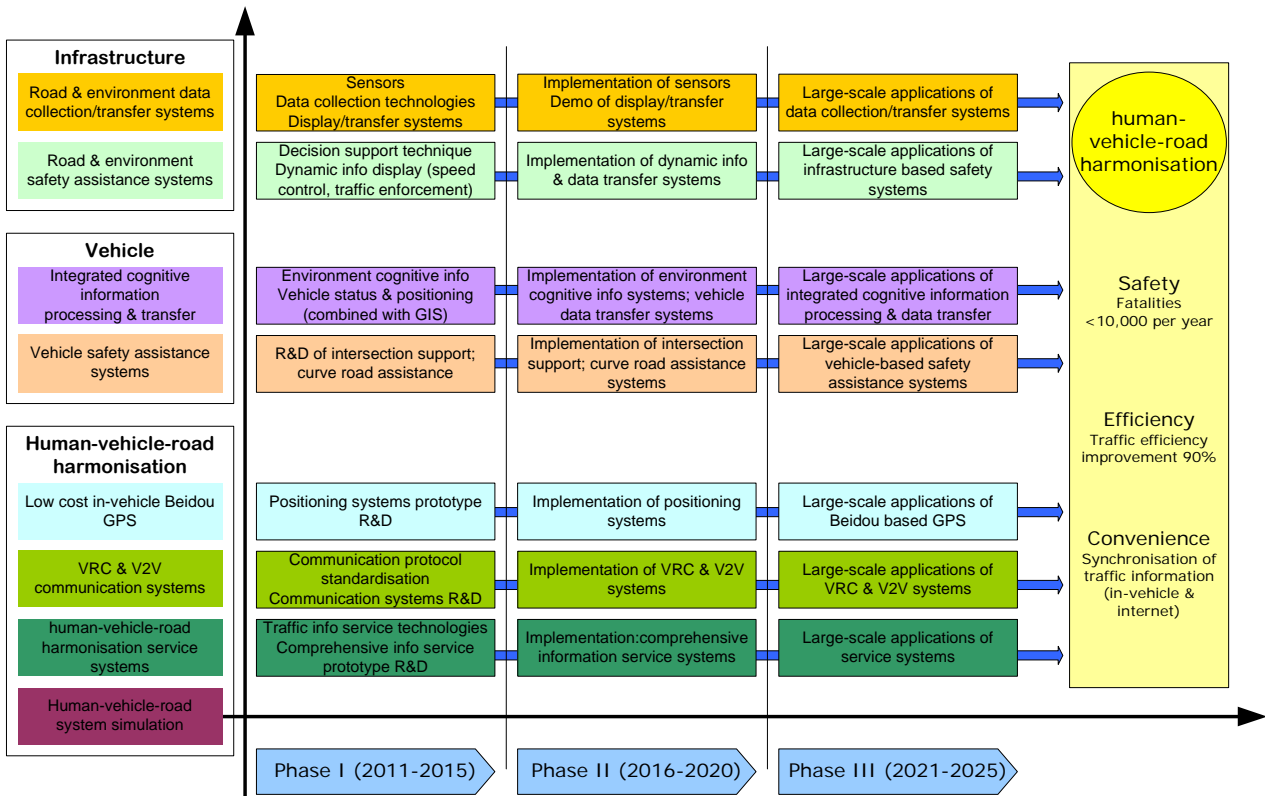
## Recommendations

Considering the current situation of pedestrian safety in China and the best practice in western countries, the following four categories of available countermeasures are proposed to effectuate the improvement of pedestrian safety.

1. Legislation and traffic regulations. This includes the change and improvement of vehicle requirements, infrastructure requirements, road traffic rules, and driving license requirements. In addition, the legal rights of pedestrians should be ensured.
2. Measures directly acting on driving behaviour. Measures in this category are often promoted by traffic surveillance and enforcement, information, education and driving instruction and

dynamic traffic management. In China, the traffic-violating behaviour of pedestrians should be especially addressed and reduced.

3. Road infrastructure related measures, which include specific measures at both intersections and road sections, and generic measures (applying to the network as a whole). Road (re)design should follow traffic safety principles: 1) road network functionality; 2) recognisability and predictability; 3) traffic homogeneity; 4) driving task simplification; and 5) error forgivingness (see e.g. [Lu, et al., 2006, Wegman & Aarts, 2006]).
4. Vehicle related measures. The measures include passive components like car structure, head restraint, seatbelts and airbag, and active components like quality of tyres, and in-vehicle driving assistance systems. Previous research has shown that active safety systems mainly contribute to the reduction of accident risk [Lu, 2006], and therefore to an increase of road traffic safety.



GPS - Global Positioning System  
R&D: Research & Development

GIS - Geographic information system  
VRC - Vehicle Road Communication

V2V - Vehicle to Vehicle

Figure 3 - Roadmap of human-vehicle-infrastructure harmonisation for traffic safety, traffic efficiency and convenience

A roadmap for the harmonisation of human, vehicle and infrastructure for traffic safety, traffic efficiency and convenience is illustrated in Figure 3. In summary, through comprehensive implementation of various countermeasures, pedestrian safety could be substantially improved. However, from a theoretical and a practical perspective, accident probability and the number of accidents cannot be zero.

## Conclusions

Road traffic accidents are perceived as a major societal problem in China, as well as in other countries. Road traffic safety is a complicated issue, composed of various known and unknown factors, and controllable and uncontrollable parameters. Explanations for the possible causes of accidents that involve pedestrians, as well as the reasons why pedestrian safety is not yet, but

needs to become a topic of high priority in China are provided based on logical reasoning. In addition, the study addresses which initiatives should be taken and how policy changes could be effectuated.

The proposed grey forecasting model GM (1,1) provides a powerful tool for modelling discrete series with few data (at least four) based on determination of a fundamental exponential pattern. It should be noted that the proposed approach is equally applicable to model and forecast data of other countries at a national or regional level. In principle, it is impossible to forecast the future. However, certain methods can provide scenarios of the future and estimate their likelihood based on current circumstances and knowledge. As such, they can provide useful planning information for decision making. Three policy scenarios are made based on the analysis of the forecasting results. Among these, scenario 2 seems the most plausible, i.e. to implement cost-effective countermeasures comprehensively at the national level.

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