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Dynamic Macro Analysis for Traffic Safety Experience

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Abstract

This paper describes traffic safety approach for developing countries through advanced country historical experience analysis. As for traffic safety analysis, Smeed's Law is chosen in which number of fatal accidents is function of population and number of vehicles. These parameters in Smeed's Law only affect only growing fatal accidents number as each country because there is no parameter which reduces fatal accidents number in the equation. Authors enhance Smeed's Law by adding infrastructure parameter i.e. traffic signal installation. There are many parameters other than traffic signal which drive traffic safety such as traffic regulation, education, traffic information equipment etc. Authors choose traffic signal installation as representative parameter and estimate index by analyzing Japanese historical records with dynamic transition method Lagrangian. Then authors collect numbers of fatal accidents, vehicle registration, and traffic signal installation in India and then apply enhanced Smeed's Law to Indian record. According to new analysis with enhanced Smeed's Law, it becomes clear that traffic signal installation is required for reduction of fatal accidents but it is only effective for reduction of growing speed of fatal accidents. In order to change from slowdown of fatal accidents to drop its number, our conclusion of research is that it is necessary to add more solutions how to keep traffic signal by drivers and residents. In this paper, it shows that advanced countries experience of traffic system and management becomes more crucial for traffic control system in developing countries by enhanced Smeed's law analysis.

Keywords: traffic Safety, fatality analysis, Smeed' law, lagrangian, per capita GDP

1. Introduction

The aim of this research is about how to use advanced countries traffic management experience for emerging countries traffic problem. The uniqueness in this paper is to analyze Japanese traffic fatality by dynamic quantitative method—Lagrangian—, and pick up traffic related parameters by enhancing traditional Smeed's Law equation.

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Nomenclature

D	number of fatalities	a	optimum constant value
n	number of vehicles	b	optimum constant value
p	population	α	constant of Smeed's Law (vehicle)
s	number of signals	β	constant of Smeed's Law (population)
e	natural legalism	γ	constant of enhanced Smeed's Law (signal)
c	consumption of RBC model	r	interest rate of RBC
ρ	satisfaction rate of RBC model	$d(t)$	fatality function of time
K	constant value	L	Lagrangian
λ	Lagrangian undermined constant		

1.1. *Background*

Recently it becomes big issues about environmental destruction and social loss by traffic accident and heavy congestion in emerging countries, especially in India, where unbalance between infrastructure implementation and rapid economic growth makes more difficult for solution. According Indian macro trend report, population in India by 2021 will becomes 1.4 billion and continue its growth to 1.7 billion by early 2060, as the result population in India becomes number 1 in the world. And number of vehicle in India becomes from 3 million in 2013 to 9.3 million—three times more—[ID Power research report].

When we look at Japanese history of traffic condition during fifty years, Japan had also same condition before, especially year 1970 when traffic fatality was 16,765. The current fatality in Japan is 3,694 in 2017, which is one fourth of that in 1970. After 1970, Japanese government has started many traffic policy and put lots of effort for improvement against those situation. Therefore authors try to analyze this improvement and use those experience to apply some solution to the emerging countries.

Authors have a chance to review about Japanese traffic historical condition and focus on traffic infrastructure improvement such as signal implementation, operation center setting, and signal control system and so on. In this paper, author try to make numerical analysis for traffic infrastructure improvement by dynamic macro analysis—Lagrangian—which is widely used for macro-economic analysis.

1.2. *Analysis Methodology*

In terms of traffic fatalities analysis, authors take one of traditional method "Smeed's law". The Smeed's law is proposed by Smeed R.J. English traffic researcher in 1949. The Smeed's law provides experimental equation for fatality by using relationship with vehicle number and population. And many researchers have analyzed several countries by Smeed's law equation and concluded its validness especially early stage of traffic growing. But the Smeed's law equation is limited for analysis because this equation is only used vehicle number and population which means that those parameter works increasing fatalities when economic keeps growing. There is no parameter which provide decreasing function of traffic fatalities in the past Smeed's equation. We need enhancement for the past Smeed's law equation. This is described in the next chapter.

The next key methodology traffic safety analysis is reported in the working paper "Traffic Fatalities and Economic Growth" from World Bank. In this working paper, there is a relationship between traffic fatalities and economic growth such as per capita GDP. This analysis is also commonly used for understanding fatalities potential in several countries. Therefore we analyze both cases in Japan and India in the next chapter.

Finally we also introduce Lagrangian dynamic macro analysis for estimation of fatalities in India on the basis of Japanese case study. Lagrangian function has been used for physics from original. But it is used widely used not only physics but also economics and others. The point of Lagrangian usage takes advantage for the analysis to find the maximum and the minimum value in multivariate analysis for balance solution among multiple parameters. Therefore authors choose Lagrangian for the enhanced Smeed's law equation which shall be balance between fatalities increasing factor—vehicle number, population— and decreasing factor—signal installation—. This is also described in the next chapter.

2. Analysis preparation

2.1. Smeed's law

In 1946, Smeed R.J. announced the relationship about fatalities in countries by vehicle number and population using Smeed's law equation (1). On basis of several countries analysis, the result of Equation fits the trend of fatalities by this analysis.

$$D = 3 \times 10^{-4}(np^2)^{\frac{1}{3}} \tag{1}$$

As the result of using Smeed's law in 20 countries data of Europe and United States in year 1938, the calculated fatalities fitted with data of their record.

On the basis on Smeed's law calculation and fatalities record, it shows the comparison results in India and Japan in Fig.1 (a) and (b). The Smeed's law calculation result follow the trend of each country at the first stage. After years, the gap between Smeed's law calculation and fatalities record becomes bigger, especially in Japan case. The reason of the gap comes from Smeed's law equation limitation because of using parameters—vehicle number, population—which work only for increasing side as their economy grows.

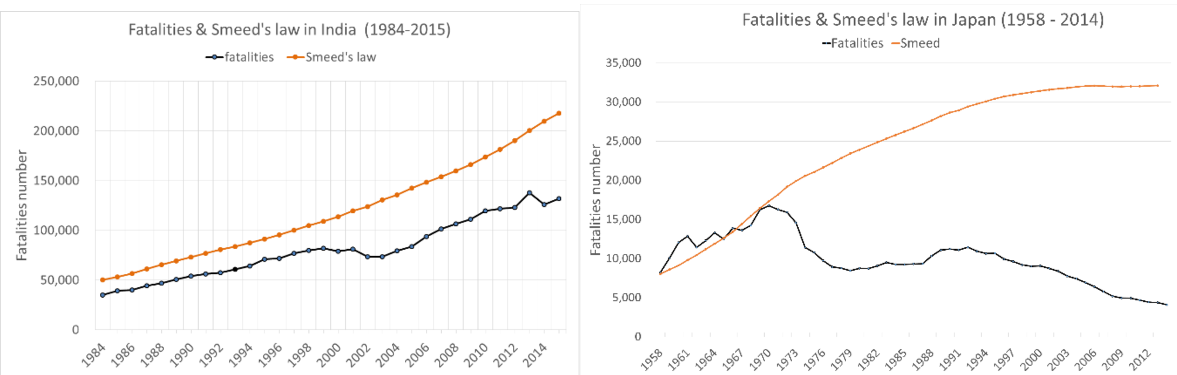

Fig. 1. (a) Fatalities and Smeed's law (b) Fatalities and Smeed's law.

2.2. Fatalities and per capita GDP

On basis of the working paper "Traffic Fatalities and Economic Growth" from World Bank fatalities research, we have two graphs for each countries Japan and India in Fig.2. One is relationship between fatalities per 1000 vehicles to per capita GDP (Fig. 2(a)) and the other is fatalities to per capita GDP (Fig. 2(b)).

From Fig.2 (a), fatalities per 1000 vehicles decreases as long as per capita GDP growth. We assume this declaration of fatalities per 1000 vehicle is able to be achieved by economic growth together with infrastructure improvement. However when we see Fig. 2(b) about fatalities to per capita GDP, fatalities increases as long as economic growth by some level of GDP. This graph shows that in early stage of economic growth, fatalities goes to higher against infrastructure improvement but at some level point of per capita GDP, infrastructure improvement stops increasing of fatalities. From Fig. 2 (a) and (b), India is at earlier stage compared with Japan. Therefore it is worth to review and analyze Japanese traffic management.

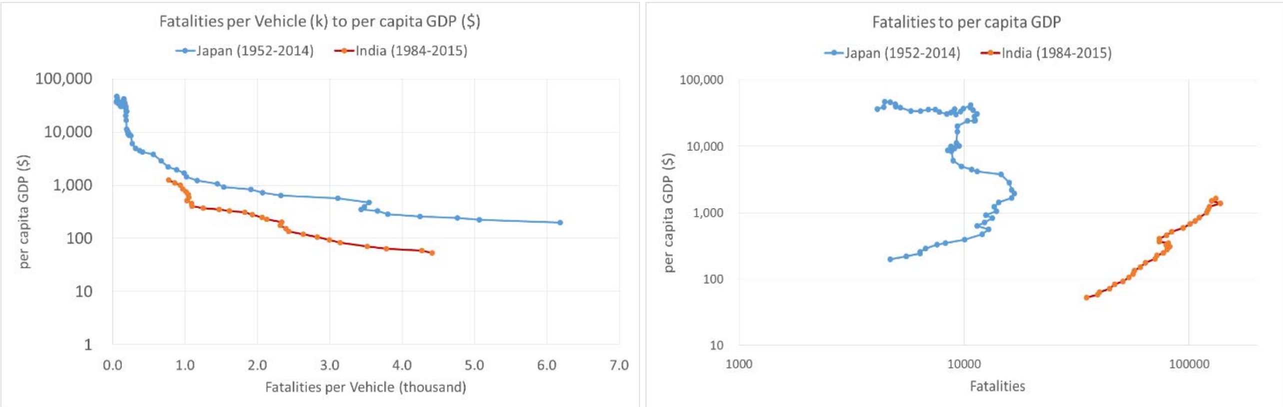

Fig. 2. (a) Fatalities per 1000 vehicle to per capita GDP (b) Fatalities to per capita GDP

From Fig. 2(b), it is necessary to define Japanese fatalities trend more detail in order to start quantitative analysis in the next chapter. Let's take Fig.2 (b) and divide into several phases on the basis of similar fatalities trend in each phase. Fig.3 (a) and (b) show an example of separation of fatalities characteristics with seven phase. Fig.3 (a) shows per capita GDP trend for each year and Fig.3 (b) shows fatalities to per capita GDP which is already shown in Fig.2 (b). According to Fg.3 (b), the points from A to D are defined by the boundary points by trend of fatalities characteristics. But point E and F are defined from time basis of per capita GDP in Fig.3 (a).
As the result, we have seven phases of fatalities trend in Japan, which are shown in Table.1.

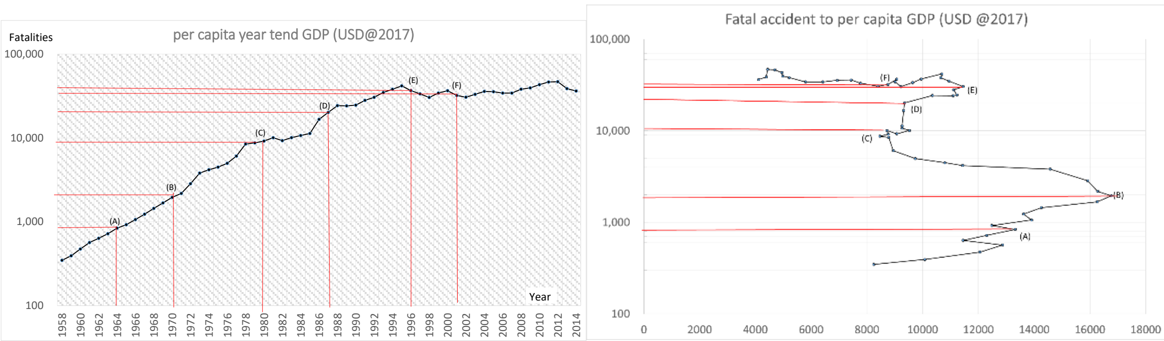

Fig. 3. (a) per capita GDP Trend in Japan (b) Fatalities to per capita GDP in Japan

Table 1. Fatalities trend of phases in Japan.

Phase	Position of point	Year
1	Start - A	1958 - 1964
2	A - B	1965 - 1970
3	B - C	1971 - 1980
4	C - D	1981 - 1987
5	D - E	1988 - 1996
6	E - F	1997 - 2001
7	F - End	2002 - 2014

2.3. Enhanced Smeed's law

As we see previous section 2.1 and 2.2, it is clear to necessity for improvement of conventional Smeed's law equation, which means adding some parameter for avoiding increasing fatalities into Smeed's law equation such as traffic management policy. Here authors propose new concept adding infrastructure improvement parameter by focussing on traffic signal installation as example. There are many factors for protecting traffic accidents not only signal but also road expansion, by-pass route, white lane, traffic operation center and even education. But we choose signal installation in this paper because it is countable from history and signal works more direct to prevent traffic accidents. There is another possibility to add multiple parameters for protecting traffic accidents but at this moment new enhanced Smeed's law equation must be simple. As enhanced Smeed's law equation, authors propose equation (2) as following.

$$D = An^{\alpha}p^{\beta}s^{-\gamma} \tag{2}$$

Where A is a constant, α is an exponential constant of increase of vehicles, β is an exponential constant of increase of population, and γ is an exponential constant of installation of signal. The γ is our new parameter which works for reducing fatalities with minus sign. Now we define equation (2) as the enhanced Smeed's law equation here.

2.4. Lagrangian

In order to dynamic transition analysis, the Lagrangian is well known in many field such as physics, space science, even in economics. The Lagrangian works under balanced environment in general. As an example, there is RBC (Real Business Cycle) model which is introduced by F.P.Lamsey in macroeconomics field. From here, we look at RBC model equation because this equation model is quiet similar of the enhanced Smeed's law by Lagrangian.

When we put consumption function as c(t) , economic interest rate r, and satisfaction rate ρ, the following equation (3) is obtained.

$$\frac{\dot{c}}{c} = r - \rho \tag{3}$$

Where $\dot{c}$ is time differentiation.

From mathematic definition, equation (4) is obtained.

$$\frac{d}{dt}(\log c(t)) = \frac{\dot{c}}{c} \tag{4}$$

When we use equation (4) relation to enhanced Smeed's law equation (2) and define time function fatalities d(t) of D, equation (5) is obtained.

$$\log d(t) = \log A + \alpha \log n + \beta \log p - \gamma \log s \tag{5}$$

From using the right side of equation (4) to equation (5), the following equation (6) is obtained.

$$\frac{\dot{d}}{d} = \alpha\frac{\dot{n}}{n} + \beta\frac{\dot{p}}{p} - \gamma\frac{\dot{s}}{s} \tag{6}$$

When we use the recursion formula between time t and t+1, the right side of equation (4) becomes equation (7).

$$\frac{c(t)\Delta t}{c} = \frac{c_{t+1} - c_t}{c_t} \tag{7}$$

Then the right side of equation (7) is expressed as equation (8) considering time lag. Here capital C_t is defined as the rate of change of consumption between time t to t+1.

$$C_t = \frac{c_{t+1} - c_t}{c_t} \tag{8}$$

When this format is applied to equation (6), it can be expressed as equation (9).

$$\frac{d(d)\Delta t}{d} = \alpha N_t + \beta P_t - \gamma S_t \tag{9}$$

From this Equation (9), it is understood that the time function *d*(t) of the number of fatalities can be obtained. Assuming that the right side of Equation (9) is a constant in a certain period, then it is able to be obtained as shown in the following example.
When we define the right side as a constant (*K*), equation (3) is expressed to equation (10).

$$\frac{\dot{c}}{c} = K \tag{10}$$

According to equation (10), *c*(t) of equation (11) is obtained.

$$c(t) = e^{Kt} \tag{11}$$

From the equation (9) and (10), the constant (*K*) can be expressed as equation (12).

$$K = \alpha N_t + \beta P_t - \gamma S_t = r - \rho \tag{12}$$

where r is positive constant parameter and ρ is negative constant parameter. In order to get the value of *K*, it is able to use Lagrangian for analysis consumption *c*(t) as application of a conditional minimum. The Lagrangian fatalities analysis with the enhanced Smeed's law is described in the next section.

2.5. Lagrangian for Traffic model

Using equation (2) of the enhanced Smeed's law, and considering the time-difference that varies from year to year, the recursion of equation (2) is expressed by equation (13).

$$D_t + \frac{D_{t+1}}{1-r} = An_t^{\alpha} p_t^{\beta} s_t^{-\gamma} + \frac{An_{t+1}^{\alpha} p_{t+1}^{\beta} s_{t+1}^{-\gamma}}{1+r} \tag{13}$$

Here, when Lagrangian is introduced to minimize the fatalities model, Lagrangian of fatalities is able to be expressed by Lagrangian equation (14).

$$L = \log D_t + e^{-\rho} \log D_{t+1} + \lambda \left(An_t^{\alpha} p_t^{\beta} s_t^{-\gamma} - D_t + \frac{An_{t+1}^{\alpha} p_{t+1}^{\beta} s_{t+1}^{-\gamma}}{1+r} - \frac{D_{t+1}}{1+r} \right) \tag{14}$$

By using partially differentiating Lagrangian equation (14) for *Dt* and *D*t+1, equation (15) and (16) are obtained.

$$\frac{\partial L}{\partial D_t} = \frac{1}{D_t} - \lambda = 0 \tag{15}$$

$$\frac{\partial L}{\partial D_{t+1}} = \frac{e^{-\rho}}{D_{t+1}} - \frac{\lambda}{1+r} = 0 \tag{16}$$

where λ is the Lagrangian undetermined constant.

By eliminating λ from Equation (15) and Equation (16), equation (17) is obtained.

$$\frac{1}{D_t} = \frac{e^{-\rho}(1+r)}{D_{t+1}} \tag{17}$$

From equation (17), D_{t+1} is expressed by equation (18).

$$D_{t+1} = D_t(1+r)e^{-\rho} \tag{18}$$

Further, according to the conventional Smeed's law equation (1), when provided to the enhanced equation (2), the values of the indexes are α=1/3 and β=2/3, and the equation (12) is inherited as the equation (19).

$$r = \frac{1}{3}N_t + \frac{2}{3}P_t \tag{19}$$

From the above, by substituting equation (12) into Equation (19), the number of fatalities (Dt+1) in the next year can be determined by equation (20) by using the vehicle increase rate (*N*t), the population increase rate (*P*t), and the traffic signal installation increase rate (*St*) if the number of fatalities (*D*t) in this year is known.

$$D_{t+1} = D_t\left(1 + \frac{1}{3}N_t + \frac{2}{3}p_t\right)e^{-\gamma s_t} \tag{20}$$

where γ was an exponential constant representing an increase in traffic signal installation
The important concept here is that we keep exponential index α=1/3 and β= 2/3 of ordinal Smeed's law equation, not adjusting exponential indexes along with the historical record in former research. Therefore our enhanced Smeed's law keeps ordinal Smeed's law concept and just adding new parameter which works for reducing fatalities such as signal installation as for infrastructure improvement for traffic management. And it is also important of the enhanced Smeed's law analysis is using only the values of fatalities at beginning of analysis. In this study, the infrastructure improvement parameter which is signal installation ratio (γ) is introduced. The important condition is to keep some constant value during particular trend of fatalities—here, the seven phases in Japanese fatalities records shown in Table.1. Therefore it is only necessary to analyse the parameter (γ) which is able to be defined during each phase from historical record. The reason the definition of parameter (γ) from fatalities curve is valid.

3. Enhanced Smeed's law Analysis for Traffic Safety

3.1. Analysis for Japanese Traffic Safety

The analysis preparation is done in the previous chapter. As we see the result of conventional Smeed's law calculation in Fig 1(b). Now we use new enhanced Smeed's law for Indian fatalities and compare the result of the enhanced Smeed's law and that of the conventional Smeed's law in Fig. 4. It is clear that the result of the enhanced Smeed's law analysis fits the record of Japanese fatalities well (refer to Fig.4). The actual number of fatality number in 1958 is used as initial fatality number (D_0) of Lagrangian equation (14). After 1958, fatality number $(D_i)_{i=1,2,3,\,,\,n}$ are obtained by Lagrangian equation (14).

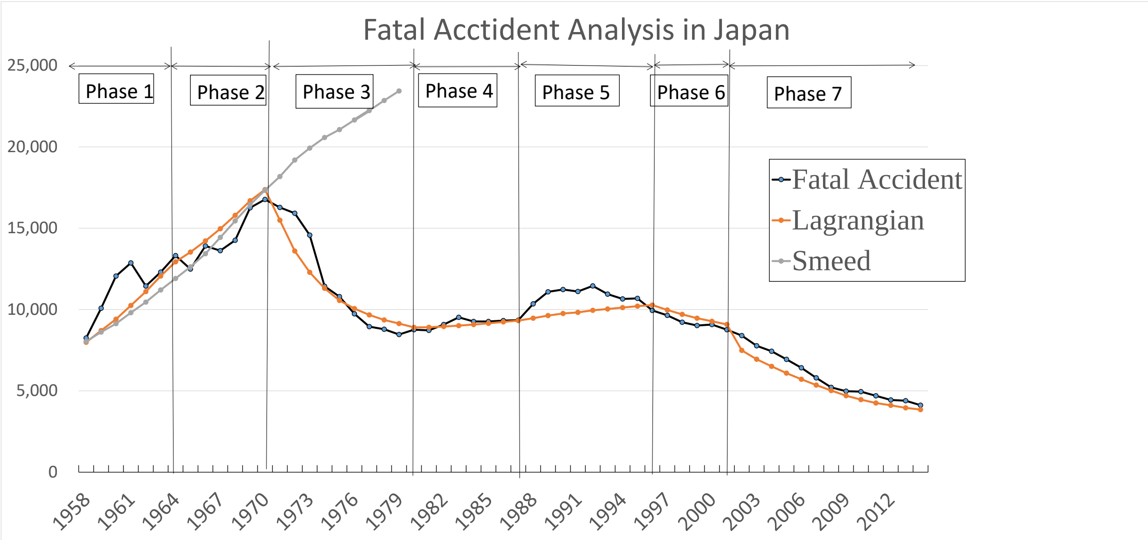

Fig. 4. Comparison between the enhanced Smeed's law and the conventional SmeedS7 law

In this new enhanced Smeed's law analysis, it is defined the new parameter (γ) as signal installation effectiveness. And this parameter (γ) takes the following value shown in Fig 5. In terms of parameter (γ), it is used as traffic signal installation. But in traffic safety management policy, there are many experience in Japan such as traffic signal installation, traffic operation centers, and advanced signal control by centralized system and even more traffic safety education for children, wearing helmet for motorcycles and so on. Japanese major policy for traffic management is listed in Table 2. As it is shown in Table 2, the signal installation has started after phased 2. And in phase 3, there are many improvement for traffic management infrastructure such as centralized control for signal, operation center setting in highways and even education. But in phase 5, parameter (γ) does not work effectively. The reason comes from that the condition was caused by much vehicle growth as shown in Fig.6. In phase 5, the vehicle traveler kilometer goes up dramatically. Therefore as the result, infrastructure improvement did not catch up against traffic accidents. After phase 5, we see that infrastructure improvement becomes effectively from Fig.5.

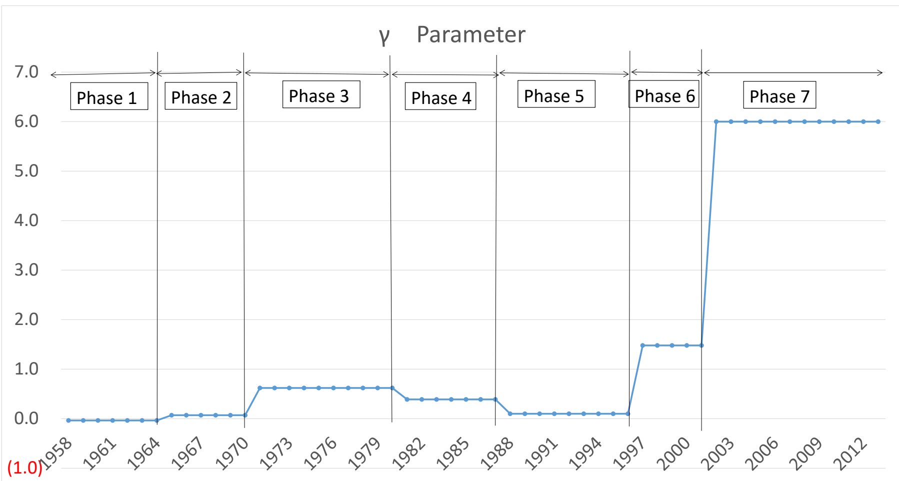

Fig. 5. Summary of parameter (γ)

Table 2.Major traffic management policy in Japan.

Year	Term	Major Policy Action & Item	Note
1958 - 1964	Phase 1	Under development for traffic management	
1965 - 1970	Phase 2	**1st Policy plan**	
		Singal development	
1971 - 1980	Phase 3	**2nd Policy plan**	
		Vehicle sensing installation	
		Sensitive type traffic signal	
1981 - 1987	Phase 4	**3rd Policy plan**	
		Central Conrol system for signal	Overall Japan
		Operation Center for traffic manegement	ditto
		Traffic regulation & More installation	ditto
		Education for traffic	ditto
1988 - 1996	Phase 5	**4th Policy plan**	
		Traffic signal algorithm improved	
		Traffic Information display	
		Network among centers	
1997 - 2001	Phase 6	**5th Policy plan**	
		ITS system development	
		Cogestion control system (VICS)	
		Optimized algorithm (MODERATO)	
2002 - 2014	Phase 7	**6th Policy plan**	
		ITS sysem installation	
		Zonening	

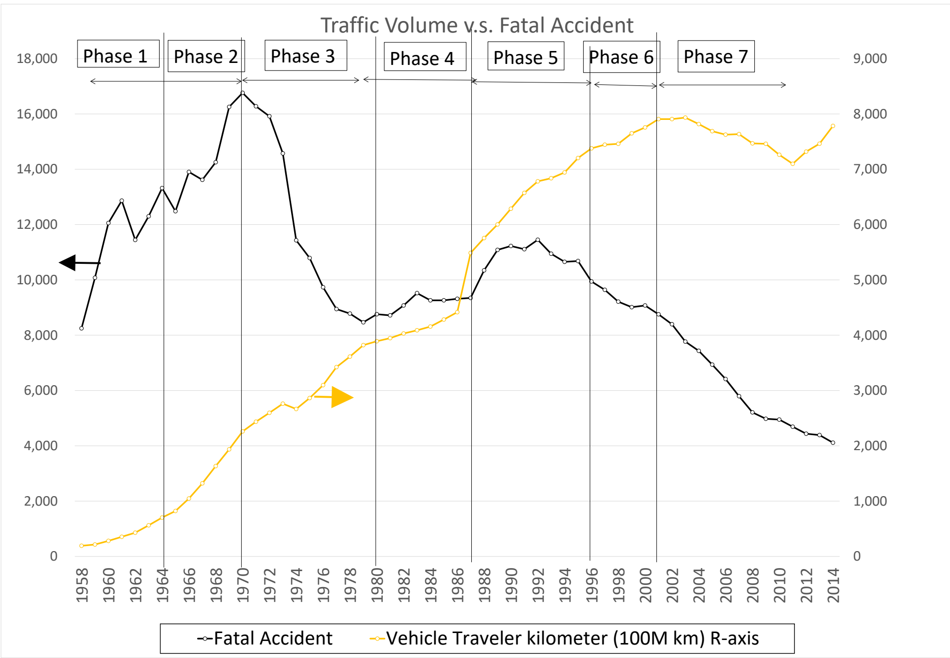

Fig. 6. Fatalities and vehicle traveler kilometer

When we see more detail infrastructure improvement such as centralized signal control and operation center placement, Fig.7 shows their installation from the record.

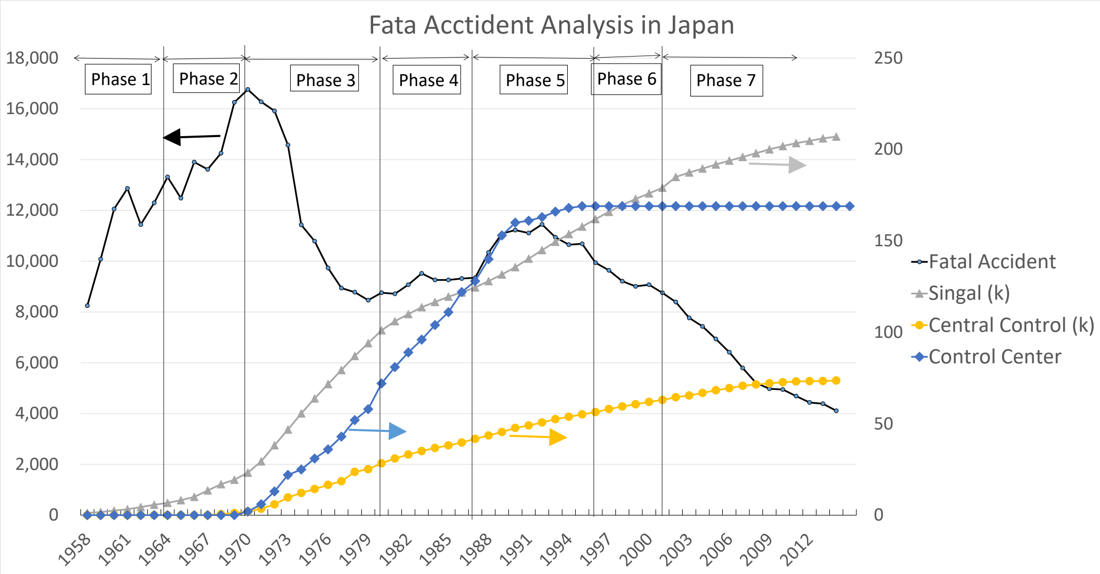

Fig. 7. Fatalities and infrastructure improvement

In terms of the parameter (γ), it is based on signal installation here. As shown in Fig.7, centralized signal control system and operational control center stated from 1970 because of more vehicle travel growth and it is not enough only to install traffic signal against such a growing traffic. Therefore interest point in this study is how much effective those new traffic management technology for traffic safety. It has already been obtained the parameter (γ) as shown in Fig.5 and the value of $D_t\exp(-\gamma S_t)$ at time (t) is constant (K_t). When it is introduced the new parameters there is a relationship among those parameters which is shown as equation (21).

$$K_t = e^{-\gamma s_t} = e^{-(k_1 S_{t+k_2} C_t + k_3 M_t)} \tag{21}$$

where K_t is constant at time (t), k_1 is a new index for signal installation (S_t), k_2 is a new index for centralized control signal (C_t), and k_3 is a new index for operational control center (M_t).

When it takes logarithm of equation (21), equation (22) is obtained.

$$\log K_t = -\gamma \log S_t = -k_1 \log S_t - k_2 \log C_t - k_3 \log M_t \tag{22}$$

then the equation (23) is obtained.

$$(\gamma - k_1) \log S_t = k_2 \log C_t + k_3 \log M_t \tag{23}$$

On the basis of Fig.7, the parameter (γ) is listed in Table 3.

Table 3.Value of parameter (γ) in each phase.

Phase	1	2	3	4	5	6	7
γ	-0.0360	0.0737	0.6303	0.3986	0.2366	1.4818	6.0487

From Fig.7, we take the value of signal installation parameter (γ) in phase 2 because phase 1 is just starting point of implementation of traffic signal as traffic management infrastructure improvement and the effectiveness of signal installation shows in phase 2. The centralized signal control system and operation control center are not started yet by phase 2. Therefore we define $\gamma = k_1$ from phase 2 to phase 5. Once these condition is defined, it is able to obtain

k_2 and k_3 from equation (21) for phase 3, 4, and 5 by multiple regression analysis. In terms of phase 6 and 7, there is no growth of operation control center. Therefore it is necessary to make multiple regression analysis between signal installation and centralized control signal. The multiple regression analysis result is shown in Table 4.

Table 4.Multiple regression analysis among traffic infrastructure.

Phase	k_1	k_2	k_3
1	-0.0360	0.0000	0.0000
2	0.0737	0.0000	0.0000
3	0.0737	0.2065	0.0308
4	0.0737	0.2065	-0.2315
5	0.0737	0.0378	0.0127
6	15.5592	-10.7803	0.0000
7	5.4504	0.3299	0.0000

On the basis of the Table 5 parameters, we use these new parameters for New Lagrangian equation (22).

$$D_{t+1} = D_t\left(1 + \frac{1}{3}N_t + \frac{2}{3}p_t\right)e^{-(k_1 s_t + k_2 C_t + k_3 M_t)} \tag{22}$$

We compare the simulation results between Lagrangian equation (19) and New Lagrangian equation (22) in Fig.8.

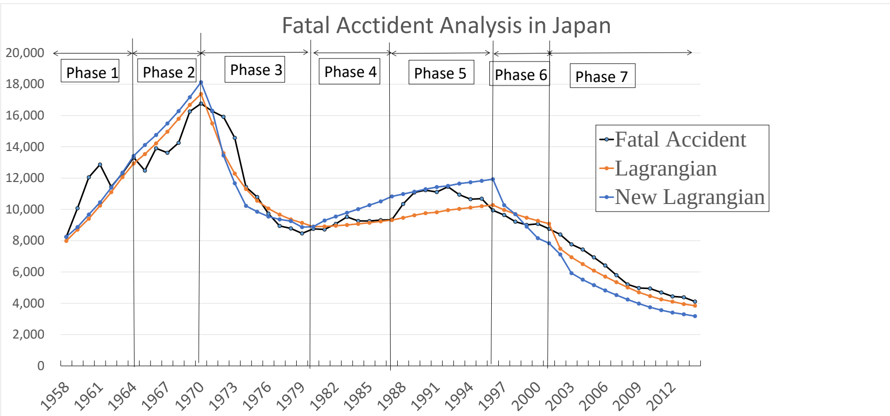

Fig. 8. Comparison Lagrangian simulation result

The difference between original Lagrangian and New Lagrangian comes from partial regression coefficients errors of New Lagrangian. But we similar results of New Lagrangian. From Table 4, we understand that centralized signal control system and operation control center have certain effectiveness for traffic safety in phase 3 and centralized signal control system may be effective even in phase 4 and 5.

3.2. Analysis for Japanese Traffic Safety

In this section, there is case study of analysis Indian Traffic model. As shown in Fig. 9, the comparison result. In the enhanced Smeed's law analysis, it is used the fatalities number in the first year 1984 data record and signal parameter installation (γ)=0 because total number of signal installation in India is only 100 in 1984.

In order to estimate more future fatalities, we need market data about future vehicle number, population, and signal installation. As for population, we use United Nation World Population Prospects 2017 data. For vehicle, it is used Government of India data and for GDP and IMF or International Monetary Fund "World Economic Outlook" data.

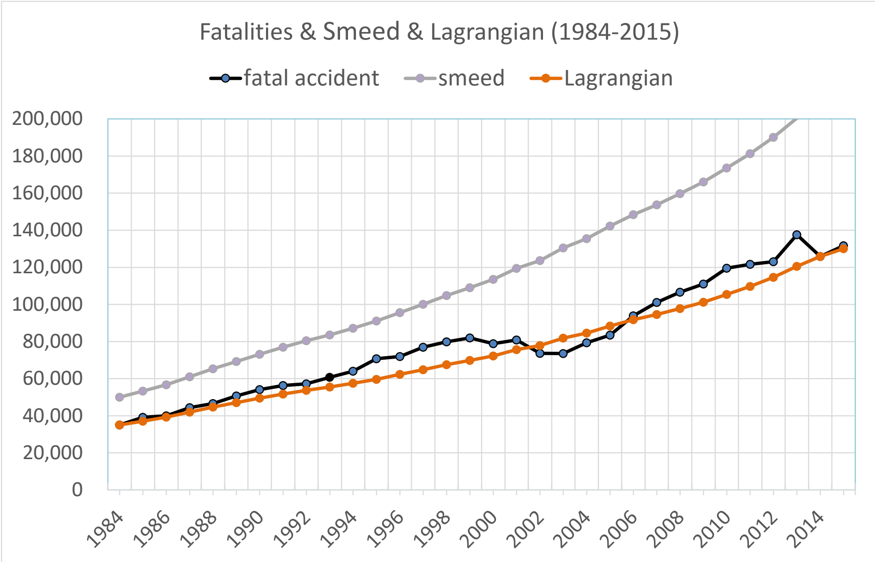

Fig. 9. Comparison between the enhanced Smeed's law and the conventional Smeed's law

In order to Indian future fatalities analysis towards 2050, it is used the enhanced Smeed's law. But there is no estimation about traffic signal installation after 2015. Therefore it is used per capita GDP growth ratio 8.5% per year. The result of future fatalities analysis towards 2050, it shows three case study. The first case is using annual 8.5% growth signal installation only. The second case is using parameter (γ) in Japanese phase 2 level plus 43% annual growth ration of signal installation. The third case is using parameter (γ) in Japanese phase 3 level plus 43% annual growth ration of signal installation. The result of this analysis is shown in Fig.10.

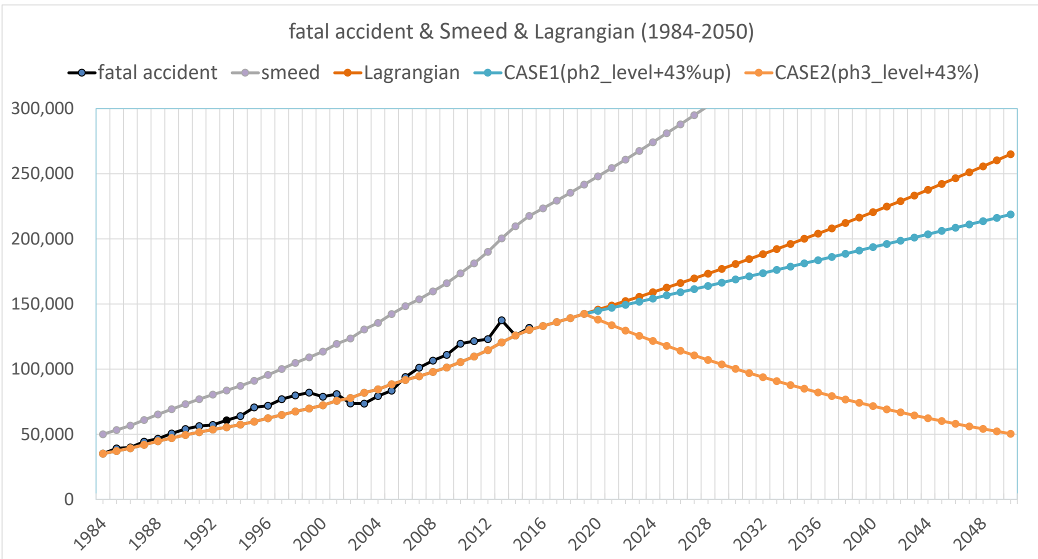

Fig. 10. Long term estimation of Indian fatalities by enhances Smeed's analysis

The reason of using three case study is that if India keeps 8.5% annual growth ratio for signal installation. The effectiveness of signal installation will not work reducing fatalities as we see in Fig. 10. Then it is necessary to have cut and try when Indian fatalities will go drop after 2020. The conclusion of this analysis is as follows:

- Japanese phase 2 level works slightly slowdown of fatalities growth but not reducing level
- Japanese phase 3 level is able to start reducing Indian fatalities after 2020.

On the basis of enhanced Smeed's analysis method, it is not enough to install more signal for reduction effectiveness even if there is not enough signal installation these days. It needs that more traffic management policy has to be done in order to protect fatalities growth. According to World Bank research report again, the Indian fatalities will not decrees by 2043 on the basis of per capita GDP growth analysis. It is able to say that if Indian traffic management follows advanced countries policy step by step, the trend of fatalities also becomes similar trend to that of advanced countries.

4. Summary

Authors have a chance to review our Japanese traffic management policy in workshop in the Japan Traffic Management Technology Association in 2017. The aim of workshop focusses on how to make Japanese traffic management efforts useful to other countries, especially the developing countries who face serious traffic problem such as heavy traffic jam, many accidents, lots of fatalities, air pollution by gas, health problem by air pollution, and energy loss by jam so on. The challenge of our research is how to make measurable for traffic management policy which is normally difficult by numerical equation.

The first choice of analysis is Smeed's law which provide fatalities estimation by using relationship between fatalities and vehicle number plus population. Several researchers have examined Smeed's law for more than 20 counties and it is valid for initial stage when traffic management policy is not well established. But sooner or later, the conventional Smeed's law analysis is not fit with the real record of fatalities in each countries. The reason of miss-matching between Smeed's law estimation and the real fatalities record comes from lacking of infrastructure parameter for protecting traffic accident such as traffic signal installation, more advanced signal control mechanism, traffic operation center setting at major highways etc. Authors propose new enhanced Smeed's law by introducing new infrastructure parameter by installation traffic signal. In order to use the enhanced Smeed's law, authors bring dynamic macro numerical analysis—Lagrangian—. As for Lagrangian analysis, it is important to have the condition of observation model with constant value parameters. Therefore authors break several groups of Japanese fatalities characteristics on the basis of per capita GDP relationship for fatalities. Then finally we are able to have infrastructure parameter in terms of signal installation.

The second step for expressing the enhanced Smeed's law to the developing countries i.e. India in this paper, which has difficulties about their traffic problem. The current traffic condition in India is placed the first and or second phase in Japanese history. Therefore the conventional Smeed's law relatively fits their fatalities record and Lagrangian method also fits well. According to World Bank research for Indian fatalities, it goes to down after year 2043 on the basis of per capita GDP growth. In our enhanced Smeed's law analysis, it is difficult to reduce Indian fatalities by just installing more traffic signal. It is possible to reduce the growth ration of fatalities but it does not go down even if the annual traffic installation growth becomes 43% under phase 2 level condition of Japan. But once phase 3 level condition or traffic management policy is applied, the estimated fatalities go down. Our first outlook about Indian traffic condition is relatively small installation ratio so far and it should have more signal installation in India. According to the enhanced Smeed's law analysis, it is not enough to install more traffic signal in India and it needs more adding traffic management policies at the same time. Therefore it is important for the developing countries to learn the advanced countries history such as Japan. In historically, Japan had also severe traffic history before under rapid economic growth.

Finally it is shown the new quantitative dynamic analysis with the enhanced Smeed's law is valid in this paper as an Indian case study. But it is necessary to have more analysis for other developing counties.

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Appendix A. An example appendix

. The traffic data sources in Japan is as following Table 3.

Table 3.Traffic information sources in Japan.

Item	Source
Number of vehicles registered	Motor Vehicle Inspection Registration Information Association, Motor Vehicle Holding Number Transition Table (from Showa 41 to 2008)
Total population	Statistical Bureau of the Ministry of Ministry of International Affairs, the Population of the Current on March 1 in the past, the Road transport Problem Research Society, the Historical Overview of Road Traffic Policy (Provisions), and the Historical Overview of Road Traffic Policy (Documents)
Vehicle traveller Kilometer	Japan Transport Policy Study Society, Japan Automobile Research Society, Statistics and Documents, p.84,2014
Traffic signal maintenance	Police Office Traffic Statistics, the edition from fiscal 2011 to the edition from fiscal 2017, the Study for Road Traffic Problems, the Society for Road Traffic Policy and ITS, pp. 362-363, the Major Publishing Company, 2014, the Association for Traffic Control Sites, the 50-year history of traffic signals, pp. 66, 1975
Number of integrated control signals	(Public Property) Japan Traffic Management Technology Association Calculate (by the number of regional control signals + the number of automatic road-sensitive system control signals)/total traffic signal).
Number of operation centers	UTMS Association, Japan's history of traffic signals, pp. 85-86, 2016

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