Quantitative Traffic Safety Analysis for India by Japanese Experience

Tsutomu Tsuboi
Nagoya Electric Works Co., Ltd., Aichi, Japan

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 growing fatal accidents number as each country because there is no parameter which reduces fatal accidents number in the equation. Author improves Smeed’s Law by adding infrastructure parameter i.e. traffic signal installation. There are also many parameters to be considered such as traffic regulation, education, traffic information equipment, etc. Author chooses traffic signal installation as a representative parameter in this research. By using Japanese historical records, author analyzes the traffic signal installation effectiveness as a fatality reduction parameter with “enhanced Smeed’s Law”. After defining traffic safety parameter by enhanced Smeed’s Law, author applies enhanced Smeed’s Law to Indian case. According to new analysis with enhanced Smeed’s Law, author shows that traffic signal installation is required for reduction of fatal accidents but it effects for reducing fatal accidents growing speed. For the reduction of Indian fatal accidents, it is able to explain that it is necessary to add some more traffic safety policy such as introducing more intelligent traffic signal control based on Japanese traffic safety policy which has been executed during Japanese history by the enhanced Smeed’s Law analysis.

Keywords: transportation, traffic fatality, Smeed’s Law

Introduction

Recently it becomes big issues about environmental congestion in emerging countries as a negative impact of transportation. Especially in India, there is an unbalance between infrastructure development and traffic growth by its rapid economic growth. This kind of condition makes it more difficult for traffic improvement solution. According to Indian macro trend report, population in India by 2021 will become 1.4 billion and continue its growth to 1.7 billion by early 2060; as a result, population in India becomes number one in the world. And number of vehicle in India is from 3 million in 2013 to 9.3 million—three times more (Ministry of Finance Japan, 2013; J.D. Power, 2013).

When we look at Japanese history of traffic condition during 50 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 policies and put

Tsutomu Tsuboi, Ph.D., SATREPS Project Leader, Global Business Development Office, Nagoya Electric Works Co., Ltd., Aichi, Japan.
lots of efforts for improvement against those situations. Therefore author tries to analyze this improvement and uses those experiences to apply some solutions to the emerging countries (National Police Agency, 2005).

In order to make Japanese traffic analysis, author chooses “Smeed’s Law” which has been introduced by R. J. Smeed who found special relationship between the number of fatalities and the number of population and that of vehicle in the countries and announced as Smeed’s Law in 1949 (Smeed, 1949). This relation is the epoch-making empirical rule which relates traffic accident fatality to the traffic jam by the development of countries.

However, author found that the Smeed’s Law was effective only under early economic growth stage. In other words, Smeed’s Law becomes difficult to explain the trend of fatality of advanced countries like United States of America, European countries, and Japan because of no fatality reduction parameter in the current Smeed’s Law. In this paper, author enhances the Smeed’s Law by adding new fatality reduction parameter and proposes it as the enhanced Smeed’s Law. By using this enhanced Smeed’s Law, author analyzes Japanese fatality and defines new fatality reduction parameter from Japanese historical fatality data. The detail of methodology is described in the next section.

Models

Before the analysis method used, the models and their parameters required for the analysis, and the limitations of the empirical rules of Smeed in the previous study, are described.

Smeed’s Experimental Formula

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

\[ D = 3 \times 10^{-4} (np^2)^{1} \]  

(1)

where \( D \) is the number of fatalities, \( n \) is the number of vehicle registrations, and \( p \) is the population.

In Smeed’s analysis among 20 countries in 1938, he shows that result of equation (1) for each country is valid. However, there are several critical opinions about Smeed’s Law because of simplicity of the equation. For these criticism, J. Adams (1987) stated that Smeed’s Law is not perfect comparison but it is useful for perspective for traffic fatality research and shows that case study of Malaysia in 1980 is similar trend of United States in 1925.

In terms of Smeed’s Law analysis in Japan, K. Tamura (2013) intr oduced to evaluate the Smeed rules of thumb for traffic accident fatalities. Based on regression analyses, the estimation number of traffic accident fatalities was five phases as follows:

Phase 1: before 1970
Phase 2: 1970 to 1979
Phase 3 :1980 to 1992
Phase 4: 1993 to 2005
Phase 5: after 2006

The five phases’ separation is defined by the observation of the fatality.

In this study, Tamura annualizes Japanese historical record. The basic method is using equation (2) from equation (1) and making nonlinear regression analysis and defining appropriate parameters (a) and (b) of equation
(2) adjustment close to Smeed’s Law.

\[ \log \left( \frac{O}{P} \right) = a + b \log \left( \frac{a}{P} \right) \]  

(2)

The conclusion of the analysis fits the result to the actual record before 1970 (phase 1).

**Subsection**

On basis of Smeed’s Law and fatalities record, author calculates the comparison between India\(^1\) and Japan\(^2\) case in Figures 1(a) and 1(b). The Smeed’s Law result follows the trend of each country at the first stage, which is the same conclusion of Admas and Tamura reviews. After 1970, in Figure 1(b), there is big gap between Smeed’s Law and fatalities record. The reason of this gap comes from Smeed’s Law equation limitation because of Smeed’s Law parameters—vehicle number, population—which work only for increasing side according to economy grows.

![Figure 1](image)

**Figure 1.** Case study of Smeed’s Law and comparison of fatality in India and Japan.

In order to understand the analysis and its gap, author investigates Japanese economic growth and traffic safety policy in the next section.

**Economic Growth and Japanese Traffic Safety Policy**

On basis of the working paper “Traffic Fatalities and Economic Growth” from World Bank fatalities research (Kopits & Cropper, 2003), we have two graphs for each country of Japan and India in Figure 2. One is relationship between fatalities per 1,000 vehicles to per capita GDP [see Figure 2(a)] and the other is fatalities to per capita GDP [see Figure 2(b)].

From Figure 2(a), fatalities per 1,000 vehicles decrease as long as per capita GDP grows. We assume that this declaration of fatalities per 1,000 vehicles is able to be achieved by economic growth together with infrastructure improvement. However when we see Figure 2(b) about fatalities to per capita GDP, fatalities increase as long as economy grows by some level of GDP. This graph shows that in early stage of economic growth.

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\(^1\) Several reports from the following online data at: http://www.unescap.org/sites/default/files/2.12.India_.pdf; https://faculty.franklin.uga.edu/amandal/sites/faculty.franklin.uga.edu.amandal/files/Fatal_accidents_in_Indian_Coal_Mines.pdf; http://pibphoto.nic.in/documents/rlink/2016/jun/p20166905.pdf; http://www.indiansamourai.com/media/01/02/1143592970.pdf; http://www.sciencedirect.com/science/article/pii/S0386112111000227; http://www.bvmengineering.ac.in/misc/docs/published-20papers/civilstruct/Civil/101026.pdf.

\(^2\) Ministry of Land, Infrastructure, Transport and Tourism data record, online at: http://www.mlit.go.jp/road/road/traffic/sesaku/data.html.
growth, fatalities go higher against infrastructure improvement but at some level point of per capita GDP, infrastructure improvement stops increasing of fatalities. From Figures 2(a) and 2(b), India is under the early stage condition of the relationship between the fatality to per capita GDP from comparison that of Japan.

(a) Fatalities per 1,000 vehicles to per capita GDP

(b) Fatalities to per capita GDP

Figure 2. Fatality to per capita GDP relationship in Japan and India.

In terms of fatality trend to economic growth in Japan, Figure 3(a) shows Japanese per capita GDP from 1958 to 2014. And Figure 3(b) shows fatalities to per capita GDP.

(a) Per capita GDP trend in Japan

(b) Fatalities to per capita GDP in Japan

Figure 3. Per capita GDP trend and fatality to per capita GDP.

According to Figures 3(a) and 3(b), there are seven different fatality trends from 1958 to 2014, which means seven different phases in Japanese fatality history. The previous study of Tamura uses personal observation for the fatality trend phases but it is more reasonable separation to use fatality and per capita GDP observation. Table 1 shows the seven phases separation for Japanese fatality trend.

There is the major list of Japanese traffic safety policy (Ministry of the Environment, 2017; International Association of Traffic and Safety Sciences; 2012)\(^3\) in Table 2 according to Table 1 of phase separation.

- Phase 1 (1958-1964): It is under development traffic management against increasing of traffic fatality in Japan.
- Phase 2 (1965-1970): In this term, Japanese government deploys more traffic signal installation in major streets.

\(^3\) Ministry of Land, Infrastructure, Transport and Tourism reference report. Policy plan based on transport basic policy. Retrieved from http://www.mlit.go.jp/common/001080289.pdf.
• Phase 3 (1971-1980): It is using sensitive traffic signal system with using vehicle sensing installation, which manages shorter length of waiting vehicle queue.

• Phase 4 (1981-1987): The central control system for signal is used, which is controlled by operation center for traffic management. Its installation is expanded to more location. There are also savior traffic regulations which are examined such as putting on helmet for two wheelers.

• Phase 5 (1988-1996): The traffic signal control algorithm has been improved. The traffic information displays are installed in highways. It is installed with network system among traffic signals.

• Phase 6 (1997-2001): The Intelligent Transport System (ITS) is developed. The congestion control system (VICS) and optimized algorithm (MODERATO) are installed.

• Phase 7 (2002-2014): The ITS system is installed as commercial operation which is allowed to communicate between vehicle to infrastructure such as traffic signal and vehicle to vehicle for avoiding collision. In urban area, zoning system is applied.

Table 1

| 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 |

Table 2

| Year       | Phase | Major action & item                  | Note           |
|------------|-------|--------------------------------------|----------------|
| Before 1964| Phase 1| Under development for traffic management | Note           |
| 1964       | Phase 2| 1st policy plan                      | 2nd policy plan |
|            |       | Signal implementation                | Vehicle sensing installation |
|            |       |                                       | Sensitive type traffic signal |
| 1970       | Phase 3| 3rd policy plan                      | Overall Japan |
|            |       | Central control system for signal    | 3rd policy plan |
|            |       | Control center for signal control    |                 |
|            |       | Traffic regulation & more installation |                 |
|            |       | Education for traffic                |                 |
| 1980       | Phase 4| 4th policy plan                      |                 |
|            |       | Traffic signal algorithm improved    |                 |
|            |       | Traffic information display          |                 |
|            |       | Network among centers                |                 |
| 1987       | Phase 5| 5th policy plan                      |                 |
|            |       | ITS system development               |                 |
|            |       | Congestion control system (VICS)     |                 |
|            |       | Optimized algorithm (MODERATO)       |                 |
| 1996       | Phase 6|                                       |                 |
Enhanced Smeed’s Law

As we see in previous sections, it is clear to necessity for improvement of conventional Smeed’s Law equation, which means adding some parameters for avoiding increasing fatalities into Smeed’s Law equation such as traffic management policy. Here author proposes new concept of adding infrastructure improvement parameter by focusing on traffic signal installation as example. There are many factors for protecting from 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 from traffic accidents but at this moment, new enhanced Smeed’s Law equation must be simple. As enhanced Smeed’s Law equation, author proposes equation (3) as following.

\[ D = An^{\alpha}P^{\beta}S^{-\gamma} \]  \hspace{1cm} (3)

where \( A \) is a constant, \( \alpha \) is an exponential constant of increase of vehicles, \( \beta \) is an exponential constant of increase of population, and \( \gamma \) is an exponential constant of installation of signal. The \( \gamma \) 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.

Analysis With Enhanced Smeed’s Law

From equation (3), the number of fatality \( D \) is time function \( d(t) \). It takes the logarithm of both parameters of equation (3), then equation (4) is obtained.

\[ \log d(t) = \log A + \alpha \log n + \beta \log p - \gamma \log s \] \hspace{1cm} (4)

When equation (4) is differentiated by time \( t \), equation (5) is obtained.

\[ \frac{d}{dt} = \frac{\alpha}{n} + \frac{\beta}{p} - \frac{\gamma s}{s} \] \hspace{1cm} (5)

When we use the recursion formula between time \( t \) and \( t+1 \) of the fatality function \( d \), it is expressed by equation (6).

\[ \frac{d(t)\Delta t}{d} = \frac{d_{t+1} - d_t}{d_t} \] \hspace{1cm} (6)

When the left side of equation (6) is expressed by \( D_t \), equation (6) is expressed by equation (7).

\[ D_t = \frac{d_{t+1} - d_t}{d_t} \] \hspace{1cm} (7)

From equations (6) and (7), equation (5) is expressed by equation (8).

\[ \frac{d(t)\Delta t}{d} = \frac{D_t}{d} = \alpha N_t + \beta P_t - \gamma S_t = r - \rho \] \hspace{1cm} (8)

where \( N_t, P_t, \) and \( S_t \) are the number of vehicles, population, and signal at time \( t \). The \( r \) and \( \rho \) are positive value and negative value of equation (8).

When the left side of equation (5) is some constant \( K \) value, it is expressed by equation (9).
From Euler’s 2nd formula, equation (9) is expressed by equation (10).

\[
\frac{d}{dt} = e^{rt}
\]

Then from equations (8) and (10), equation (11) is obtained.

\[
d(t) = e^{rt} = e^{(aN_t + \beta P_t - \gamma S_t)t} = e^{(r - \rho)t}
\]

From equation (11) style point of view, we see similarity of the equation of RBC (Real Business Cycle) model of F. P. Ramsey (1928) in macroeconomics field which is described by K. Nishii in his “Macroeconomic Implications of the Ramsey Model: Consumer Optimization and Endogenous Growth” (Nishii, 2016). According to RBC model, \( r \) represents interest of bank account and \( \rho \) represents consumption. By using this theory, it is possible to use Lagrangian minimum problem method. From equations (3) and (8), it is possible to the recursion of equation (12).

\[
D_t + \frac{D_{t+1}}{1 + r} = \frac{A n_t^\alpha P_t^\beta S_t^{-\gamma}}{1 + r} + \frac{A n_{t+1}^\alpha P_{t+1}^\beta S_{t+1}^{-\gamma}}{1 + r}
\]

When using Lagrangian of fatality \( D_t \), equation (13) is obtained.

\[
L = \log D_t + e^{-\rho} \log D_{t+1} + \lambda \left( An_t^\alpha P_t^\beta S_t^{-\gamma} - D_t + \frac{A n_{t+1}^\alpha P_{t+1}^\beta S_{t+1}^{-\gamma}}{1 + r} - \frac{D_{t+1}}{1 + r} \right)
\]

By using partially differentiating Lagrangian equation (13) for \( D_t \) and \( D_{t+1} \), equations (14) and (15) are obtained.

\[
\frac{\partial L}{\partial D_t} = \frac{1}{D_t} - \lambda = 0
\]

\[
\frac{\partial L}{\partial D_{t+1}} = e^{-\rho} - \frac{\lambda}{D_{t+1}} = 0
\]

where \( \lambda \) is the Lagrangian undetermined constant.

By eliminating \( \lambda \) from equation (14) and equation (15), equation (16) is obtained.

\[
1 = e^{-\rho}(1 + r)
\]

From equation (16), \( D_{t+1} \) is expressed by equation (17).

\[
D_{t+1} = D_t(1 + r) e^{-\rho}
\]

From the above, by substituting equation (12) and equation (11) into equation (17), the number of fatalities \( D_{t+1} \) in the next year can be determined by equation (18) by using the vehicle increase rate \( N_t \), the population increase rate \( P_t \), and the traffic signal installation increase rate \( S_t \) if the number of fatalities \( D_t \) in this year is known.

\[
D_{t+1} = D_t \left( 1 + \frac{1}{3} N_t + \frac{2}{3} P_t \right) e^{-\gamma S_t}
\]

In order to make new analysis by using the equation (18), we are able to get \( \gamma \) by Japanese record for each phase.

As we see more detail in infrastructure improvement such as centralized signal control and operation center placement in Table 2, it is possible to use some more parameters which have potential to reduce fatality.
such as centralized control signal installation $C_i$ and traffic control center management $M_i$. Let us take this infrastructure parameter as equation (19), the enhanced Smeed’s Law 2.

$$e^{-\gamma S_t} = e^{-\left(k_1 S_t + k_2 C_t + k_3 M_t\right)}$$

(19)

where $k_1$, $k_2$, and $k_3$ are defined as new constant value for each signal installation $S_t$, centralized control signal installation $C_t$, and traffic control center management $M_t$. The new $k_1$, $k_2$, and $k_3$ are able to get by multiple regression analysis.

Table 3 and Figure 4 show the signal parameters $\gamma$, $k_1$, $k_2$, and $k_3$. All these parameters come from the Japanese historical record analysis result; therefore, they are representative to explain about Japanese traffic safety policy. In another word, these parameters mean the effort of Japanese traffic safety experience. Therefore, these parameters are able to use for other countries’ traffic safety analysis if some of Japanese policies are chosen in other countries. The Indian fatality analysis is explained in the next section.

Table 3

| Phase  | $\gamma$  | $k_1$  | $k_2$  | $k_3$  |
|--------|-----------|--------|--------|--------|
| Phase 1| -0.03617  | -0.03510| 0.0000 | 0.0000 |
| Phase 2| 0.09060   | 0.10448| 0.01186| 0.0000 |
| Phase 3| 0.63720   | 0.80405| -0.09375| -0.02935|
| Phase 4| 0.45880   | -0.26527| 0.26773| -0.00444|
| Phase 5| 0.25140   | 0.17728| 0.04718| -0.00112|
| Phase 6| 1.63715   | 0.71993| 0.81945| 0.0000 |
| Phase 7| 5.66039   | 2.12083| 1.65752| 0.0000 |

Figures 5(a) and 5(b) show the comparison among Smeed’s Law, enhanced Smeed’s Law, and enhanced Smeed’s Law 2.

According to the Japanese fatality analysis, traffic signal installation for reduction of fatality is effective and we introduce two types of analysis in this case, enhanced Smeed’s Law and enhanced Smeed’s Law 2. The difference of two analysis is signal parameter. In enhanced Smeed’s Law, there is only one signal installation. On the other hand, in enhanced Smeed’s Law 2, there are three parameters i.e. signal installation, centralized control signal installation, and traffic control center management. From Japanese fatality analysis, traffic signal installation is effective to reduce fatality in phases 2 and 3 and combination of signal installation and centralized control system work in phases 6 and 7.
Discussions and Results

Indian Fatality Case Study

In the previous section, we have new parameter which works for the reduction of fatality from Japanese experience. And as we see in Figure 1(a), Indian fatality trend is growing by Smeed’s Law. Figure 6 shows the comparison among Indian fatality, Smeed’s Law, and enhanced Smeed’s Law analysis. As we see, the enhanced Smeed’s Law fits well with the actual record of Indian fatality.

When we use Japanese traffic safety policy which means we use fatality reduction parameter, we have the result at Figure 7 towards 2050. In Figure 7, there are several case studies—Business as Usual (BaU) which means there is nothing special to do with traffic safety, CASE 1 which follows Japanese traffic safety phase 2 level, and CASE 3 which follows Japanese traffic safety phase 3 level. As Figure 7 is shown, it is necessary to have some countermeasures at least in Japanese phase 3 level in order to reduce the number of fatalities in India. From Table 2, phase 2 level is focused on more signal installation but phase 3 level is not only signal installation but also several improvements for traffic signal such as vehicle sensing technology and sensitive signal control by sensing vehicle condition.

Japanese Traffic Safety Policy

As we see in Table 1, Japan has executed several traffic safety policies. From Table 2, we only choose three quantitative parameters such as signal installation, centralized control signal installation, and control
center management as representative fatality reduction parameters. In terms of these safety policies of signal related, it is assumed to have co-relationship among them. But in Table 2 parameter value, we use an independent parameter. Therefore, each value of parameter shows exact effectiveness for fatality reduction. The case of actual number of each traffic safety policy is shown in Figure 8. From Figure 8, signal installation has started in phase 2 and in addition to this, centralized control signal and control center have been set in phase 3. From here, we see that Japan started multiple traffic safety policy from phase 3. In addition, there are also important traffic safety policies such as traffic safety education, helmet for motor cycles, and traffic regulation. Therefore, we need to check real Japanese policy when we use enhanced Smeed’s Law analysis in other country simulation and follow Japanese traffic safety policy experience.

![Figure 6. Indian fatality analysis by Smeed’s Law and enhanced Smeed’s Law.](image)

![Figure 7. Indian fatality analysis with Japanese traffic safety policy.](image)

**Signal Installation Effectiveness**

As we see in the previous section, the traffic signal installation works as one of fatality reduction functions. In this section, we see real effectiveness of signal installation number by comparing vehicle number and fatality number with signal installation number in both countries. Figure 9 shows those relationship. Based on this comparison, the number of signal installation in Japan grows as the number of vehicle grows and the ratio is more than 2.5 times per thousand of vehicles [see Figure 9(a)]. On the other hand, in India, the growth ratio of signal installation per thousand of vehicles is 0.07 [see Figure 9(c)]. Therefore, it is clear that the signal installation is good enough to growth of vehicles in India. In terms of fatality to signal relationship, Indian case
is at the early stage of Japan case from Figures 9(b) and 9(d). This situation is the same situation shown in Figure 2, the fatality to per capita GDP relationship.

![Figure 8. Actual number of Japanese traffic safety policy.](image)

(a) Vehicle vs. signal relationship in Japan

(b) Fatality vs. signal relationship in Japan

(c) Vehicle vs. signal relationship in India

(d) Fatality vs. signal relationship in India

![Figure 9. Traffic signal installation effectiveness comparison.](image)

**Conclusions**

In this study, we started to investigate how to improve traffic negative impact in developing countries, in this case in India and how to use Japanese traffic safety experience with somehow quantitative analysis method. And author found that R. J. Smeed’s research which he first proposed the relationship in 1949, is an empirical
rule relating traffic fatalities to traffic congestion as measured by the proxy of motor vehicle registrations and
country population as Smeed’s Law. The Smeed’s Law is simple equation to understand basic traffic condition
especially fatality in developing countries and at early stage of more than 20 countries based on several
researchers’ study. But there is a limitation to use Smeed’s Law for after certain economic growth because its
equation takes only fatality growing parameters, number of vehicles, and its population. Therefore researchers
try to change exponential index of Smeed’s Law equation which breaks the original equation relationship.
Then author tries to enhance the Smeed’s Law by adding the fatality reduction parameter such as the traffic
signal installation and keeps the original Smeed’s Law concept as much as possible. By using the enhanced
Smeed’s Law, author starts to analyze Japanese about 60 years’ historical record. As for numerical dynamic
quantitative analysis, author breaks down the Smeed’s Law equation to the recursion formula. And based on
similarity formula of macroeconomics field which is famous of RBC (Real Business Cycle) model by F. P.
Ramsey, it becomes able to use Lagrangian maximum and minimum problem for macro-economic research.
By combining this method, we are able to get traffic signal installation parameter of the enhanced Smeed’s
Law without breaking the original Smeed’s Law equation relationship between number of vehicle and the
population. After adjusting the historical record and the result of the enhanced Smeed’s Law calculation, we
use the new signal installation parameter in seven phases of which is able to be divided by the GDP condition
in Japan.

After these above preparations, then we check Indian fatality record by using this enhanced Smeed’s Law.
Based on the analysis, Indian case is at the first stage of that of Japan case study, which means that main
fatality volume comes from the original Smeed’s Law i.e. number of vehicle and its population. In another
words, Indian fatality is growing stage and it is necessary to have traffic safety policy as soon as possible.
Otherwise, Indian fatality becomes worse by its economic growth. This situation has already happened now. In
order to improve this Indian situation, we are able to use Japanese traffic safety policy experience. By using the
enhanced Smeed’s Law equation, it is able to simulate Indian future trend. And we have the following
conclusions based on this analysis.

1. More signal installation is required soon for reducing Indian fatality.
2. It is not enough to install more signal in India for reducing fatality. It helps only reducing the ratio of
growing fatality growth not declining the number of fatality itself.
3. It needs to have multiple safety policy not only just more signal installation but also centralized signal
control and the traffic control center for reduction of Indian future fatality.

As for more research of the enhanced Smeed’s Law evaluation, it requires to have analysis in advanced
countries and developing countries. In this research, we choose Japan fatality record and Japanese traffic safety
policy. Therefore, it will be different status and situation in other advanced countries such as USA and other
European countries. This should be done in future work. And additionally, this study is based on country basis
analysis. Therefore, the town based fatality analysis is becoming another challenge for future work. In Figure
10, it shows the traffic signal installation status in major cities in India compared with Tokyo, New York,
London, and Singapore. As we see from Figure 10, the signal installation of major cities in India is quite small
number compared with other cities in advanced countries. And there is more challenge for how to explain
non-quantitate value in the enhanced Smeed’s Law equation such as traffic safety regulation, traffic safety
education, traffic safety fine, etc.
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Conflicts of Interest

There is no conflict of interest.

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Appendix

The traffic data source in Japan is as following Table A.

Table A
Traffic Information Source 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 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 traveler 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, p. 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                                                                                                                         |