# Research Review about Moped Accidents and the Necessity of Time Dimensional Management in University Campus Traffic

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## Abstract

This paper discusses possible countermeasures for traffic accidents involving university students using mopeds, based on recent research findings. The first part of this paper is a review of research about traffic accidents involving mopeds. Second, we show the importance of decreasing the encounter of mopeds with large-sized vehicles in order to decrease the number of accidents, in particular the number of fatalities caused by these accidents, based on a macroscopic statistical analysis of Japanese traffic accidents classified by vehicle types. In the last part of our paper, we argue for the necessity of a time dimensional transport demand management on campus as one possible and effective way to reduce encounters between mopeds and heavy vehicles.

Key Words: moped, traffic accident, temporal traffic management, campus traffic

## Introduction

Mopeds or motorized two wheeler vehicles are excellent for cost performance and user-friendly, which is why they are frequently used especially in developing countries. As a result, the increase of traffic accidents, in particular fatal accidents poses a serious problem in many countries (Salagberu, *et al.*, 2006; Dandona, *et al.*, 2006; Haque, *et al.*, 2009). Based on empirical knowledge about problems such as a high mortality in accidents involving head injuries, frequent occurrence of accidents on right turns in intersections and frequent overlooking of mopeds by car drivers, several countermeasures have been taken in Japan, such as the compulsory use of helmets, two-step right turns in intersections, full-time lighting-up of the head light of mopeds (ITARDA, 2004). Recently, new research on the modeling of positioning

behavior of mopeds in lanes, and re-design of road sectional layouts to avoid the moped's passing-by other vehicles through a narrow clearance are executed and the restructuring of roads is now under consideration (Inagagi, *et al.*, 2007). Some of these measures have resulted in the decrease of moped accidents in Japan, and many aspects of the Japanese case may be applicable to other countries.

A typical location of mopeds accidents is on the road to university campus, where new students and less experienced moped riders replace more experienced drivers upon graduation every year. In Japan, the driving license for mopeds can usually be acquired without actual field driving training or a practical driving test. Many riders are new license holders without any driving experience of larger motor vehicles. They include young riders who easily take offensive actions due to excessive trust in their own driving ability. These factors make safety education measures difficult and less effective. Considering the economic limits of students, they cannot change their travel modes to more expensive transportation means such as four-wheel automobiles. Therefore, we cannot solely rely on safety educational measures that are limited due to the migration cycle of students. However, hardware countermeasures, such as road section redesign, are also limited in their applicability in particular given spatial and budget constraints.

This paper discusses possible countermeasures for traffic accidents involving university students using mopeds, based on recent research findings. The first part of this paper is a review of research about traffic accidents involving mopeds. Second, based on a macroscopic statistical analysis of Japanese traffic accidents classified by vehicle types, we show the importance of reducing the encounters of mopeds with large-sized vehicles, in order to decrease the number of accidents and reduce the fatalities caused by these accidents. In the second part of this paper, we argue for the necessity of a time dimensional transport demand management on campus as one possible and effective way to reduce the encounters between mopeds and large-sized vehicles.

# **Review of Research about Moped Accidents**

This section presents a comprehensive review of recent research papers about moped accidents, ranging from international journals such as Accident Analysis and Prevention, Injury, Injury Prevention, Journal of Safety Research, and so on. These papers are reviewed according to the following classifications;

- Overview of the occurrence trend of moped accidents,
- Research about the responsible persons in moped accidents,
- Research about the cause of the accident with four or more wheel vehicles,
- Research about the temporal and spatial distribution of moped accidents,
- Research about the influence of the confronting car types.

*Occurrence trend of moped accidents.* Due to being less expensive compared to four-wheel vehicles due to their flexibility even on narrow roads in downtown areas, the use of mopeds increases rapidly in the early stages of the economic development

of a country. At the same time, the number of moped accidents also increases rapidly (Salagberu, *et al.*, 2006). Legislative countermeasures and control by police usually cannot be executed prior to the rise of accidents. Head injuries of moped riders who do not wear a helmet that result in fatal moped accidents have become one of the main causes for traffic-related deaths in developing countries (Dandona, *et al.*, 2006).

Along with economic growth in later development stages of a country, the registered number of mopeds usually decreases. However, poorer people with less education continue to use mopeds. As a result, the occurrence rate of moped accidents does never decrease through economic development (Haque, *et al.*, 2009). For example in Japan, the registered number of mopeds marked 18,000,000 at its maximum in 1985 and decreased to 11,000,000 in the following two decades. The number of victims of mopeds accidents decreased accordingly from the peak number of 2,575 in 1989 to half of that number in 2003, but the occurrence rate of the accidents did not decrease (ITARDA, 2004). It is remarkable in contrast with the decrease of fatalities and serious injury percentages of accidents involving four-wheel cars, where protective air-bag and seat belts on all seats have been widely installed in the past decades.

Responsible person of the moped accidents. In any country, the responsible person and the victim killed in moped accidents are concentrated among young male riders without major driving experience (Natalier, 2001). Whether such a concentration owes to "the low age" or more specifically to " insufficient driving experience" has been debated among researchers. In a mail survey sent to moped owners in the United Kingdom, the number of accidents proved to be dependent on low age along with a more relaxed attitude toward adhering to laws and traffic rules, but the number of accidents did not correlate with little driving experience (Rutter and Quine, 1996). A comparative study of drivers responsible for mopeds accidents and roadside surveys in New Zealand showed the statistical significance of low age for the accident occurrence ratio, but again there was no dependency on the number of years of experience. These studies proved that the large number of male drivers involved in accidents is simply due to the higher usage of mopeds of men compared to women (Mullin, et al., 2000). A study based on the Spanish ten years accident database revealed that young male moped riders and drivers tend to drive at higher speed higher than other older groups. When considering the difference of speed, the accident occurrence rate for elder drivers is higher (Lardelli-Claret, et al., 2005). We can conclude that young men's aggressive tendency toward driving at highspeed results in a higher occurrence of accidents and accidents involving bicycles and pedestrians. A consciousness investigation of driving license holders in Norway reveals that teenage drivers tend to consider the use of the motorcycle as a symbol of being free, independent and young. They insisted on the importance of sociological research on the formation process of such tendencies (Nja and Nesvag, 2007).

No clear conclusions have yet been drawn on whether safety education could change the consciousness and attitude of drivers. A comparative study on the participants of two-wheel riders in a lecture program in Ontario State in Canada from 1974 to 1977 an samples of drivers of equal age and gender showed a lower percentage of traffic rule violations, but no significant difference of accident occurrence between the groups (Jonah, *et al.*, 1982). In a similar research about the lecture program in 1979 in British Columbia State in Canada, attendance to the program did not have any significant effects either on rule violation or accident occurrence percentage (McDavid, *et al.*, 1989). However, these comparative methods cannot statistically measure the effect of lecture because drivers who seek to improve safety tend to attend these lectures. An additional panel data analysis to verify a change before and after the education for the identical sample will be necessary.

*Cause of the accidents with four or more wheelers.* It is important to clarify the cause of collision accidents with other cars in order to review the avoidance plan of fatal moped accidents.

A research group in Southern California University investigated moped accidents in Los Angeles in 1976 and 1977 and showed that car's interference with the passage of the moped at the intersection caused two thirds of mopeds-car accidents (Hurt, et al., 1982). They suggested the constant use of moped's headlight and reflective color jacket wearing of riders as effective countermeasures to avoid being overlookeded by a car. This research also showed that 96 percent of the victims involved in fatal accidents are men, and that drinking prior to the moped ride was involved in half of the cases. A strict ban of drinking while driving and the wearing of helmets were proposed. However, another paper summarizing 21 experiment reports concluded that the always headlight lighting-up doesn't have any effect in an actual traffic environment (Wolf, et al., 1989). Wolf, et al., (1989) insisted that even if a moped can be seen by the car driver, if the car driver doesn't have any experience of encountering a moped before, the driver cannot recognize the motorbike as a dangerous object. Another report (ITARDA, 2008) showed that even if the existence of the moped is recognized, errors occur in case the speed and the distance of the moped are not estimated accurately. A comparative study in the EU on drivers involved in moped accidents and selected driver samples from 1999 to 2001 confirm that car drivers who have had operation experiences of a moped can understand the movement of a moped, and that they can sense the danger of a moped accident prior to the accident (Magazzu, et al., 2006).

Quite a few research results attribute the cause of moped-car accidents to the moped rider side. For example, research conducted in the United Kingdom based on a video indoor experiment and a street running experiment found a tendency of higher speed, more frequent passing and smaller distance ahead of the following car at motorbike driving comparing to for-wheel car driving, even for the identical person (Horswill and Helman, 2003). An analysis of video images taken from long-range trailer trucks that drove in southern parts of the United States and from delivery tracks in the State of Virginia attributed the cause of 80 percent of the dangerous situations to the two-wheel vehicle. Frequent entering and passing behavior with insufficient headway are detected from the video images (Hanowski, *et al.*, 2007). However, the study also observed cases with causes on the side of the road; Incompetent operation of large-

sized cars, such as approaching with insufficient headway distance between cars, sudden backward movements, the swelling curve passage and slow braking operation.

**Temporal and spatial distribution of moped accidents.** When thinking of accident prevention measures, it is important to know the temporal and spatial distribution of accidents, but the relative occurrence ratio is difficult to calculate because we cannot comprehend real traffic distributions to be used as a denominator. It is also difficult to determine whether serious accidents occur at a higher rate during the night or whether a higher fatality rate correlates with a longer time span needed for rescue transportation at night, when we observe a higher frequency of fatal accidents during the night than during day time. It is desirable to analyze the occurrence of the dangerous phenomenon through continued probe video images (Hanowski, *et al.*, 2007).

According to previous research, there is a remarkable difference between the places of the occurrence of moped accidents and the time between single moped accidents and moped accidents that involve cars. Single moped accidents frequently occur when the road surface is wet on roads with speed limit such as highways, whereas moped-car accidents tend to occur on lower ranked roads downtown, where moped traffic for daily business purposes during peak hours are often involved (Lapparent, 2006). During peak hours, the attention of car drivers tends to concentrate on larger vehicles and pedestrians just around the car, which is when a moped can be easily overlooked. Moped-car accidents at intersections are also observed frequently near the origin of short distance trips for daily purposes, and not related to the road structure or weather conditions (Hurt, et al., 1982). However, single moped accidents at night can easily turn into serious and fatal accidents due to decreased sight and higher speed (Lapparent, 2006). Research has been conducted on the installation effect of roadside ropes (Pieglowski, 2005) that prove to have a positive effect on the rope for the reduction of fatalities in severe accidents and single accidents during night hours; whereas no effect is expected for collisions that frequently occurred in the downtown area.

In some countries, strong seasonal differences in accident occurrence are observed. For example, in the northern Iranian region, fatal moped accidents tend to occur on summer weekends, and 15 percent of annual fatal accidents are registered respectively in June and in September due to the increase of traffic (Janmohammadi, *et al.*, 2009). 82 percent of all fatal accidents occur during daytime, but at the same time, around 20 percent occur within one hour starting from 9 p.m., which is the peak hour in the evening. Another statistical study conducted in Indiana State in the United States (Savolainen and Mannering, 2007) reports a high occurrence of single moped accidents in April (9.3 percent) and July (16 percent). After the adjustment of the influence of alcohol intake, which is strong in July, they calculated that the seasonal elasticity in April of single moped accident fatalities is 111 percent higher than 98 percent for July. In the same geographical area, 11 percent of the moped-car accidents occur in April, but according to the smaller helmet-wearing ratio and the lower driving speed, Savolainen and Mannering, (2007) estimate that the fatality

propensity is as low as -64 percent in April. They describe that a higher number of new or inexperienced riders in April, who resume driving after the severe winter months, causes the high occurrence of single accidents in April. However, fatal collision with other vehicles seems to be less frequent in April.

Influence of the Confronting Car Type. The larger the confronting vehicle, the greater the energy of the crash becomes and the more severe the result of the accident in moped-car accidents A calculation of a model of dynamics shows that the degree of damage is proportional to the 2.5th power of the length ratio of the two vehicles (Wood and Simms, 2002). A Bayesian statistical analysis of the slight wounds, serious injuries, and fatal accidents compared to the number of no damage accidents in France shows a higher occurrence of fatal results when the confronting vehicle is a four-wheel car, while the fatal ratio is significantly smaller if the other party involved is a pedestrian, a bicycle, or a two wheeler (Lapparent, 2006). In the same paper, public transit vehicles (tram or bus) give mopeds with a smaller occurrence of accidents involving injuries, but a higher possibility of fatal results, however, these results are not statistically significant. The Indiana moped accident study referred to earlier, shows a higher occurrence of serious injuries in case of collision with a pickup truck, and a higher occurrence of fatal accidents in case of accidents with large-sized trailer trucks (Savolainen and Mannering, 2007). Furthermore, Harrop and Wilson, (1982) report a fatal accident involving a moped through a front-to-front crash with an approaching car on the reverse lane, after the moped driver's attempt to pass by a stopping bus.

Based on the studies above, we conclude that a situation in which mopeds and largesized vehicles such as buses and trucks mingle at the same time is not desirable for traffic safety.

	Second party (affected)	Passenger car		Cargo/freight		Monodo	
First party (responsible)		bus	compact & normal	heavy	compact & normal	- Mopeus	<i>yi</i>
Passenger	bus	1	91	2	18	58	170
car	compact & normal	86	11054	66	2513	8456	22175
Cargo/freight	heavy	3	386	55	173	132	749
	compact & normal	26	3927	47	1444	2824	8268
Mopeds		13	1094	38	298	913	2356
Zj		129	16552	208	4446	12383	33718

 Table 1.
 Number of vehicle accidents in Tokyo in 2007

#### Moped and Large Vehicle Mixture and Accident Occurrence

We confirm that the mixture of mopeds and large-sized cars poses a problem in terms of the occurrence percentage and the fatality of traffic accidents, based on statistical analysis of a Japanese accident statistic database. The data to be analyzed here is a traffic accident macro statistic database in the Tokyo Area in the year 2007 by the Institute for Traffic Accident Research Data Analysis (ITARDA).

*Vehicle Type Combinations in Accident Occurrence.* The first analysis was conducted to determine the number of accident occurrences categorized by vehicle type of the first party, the more responsible actor in the accident, and the second party, the more affected actor, based on the observed numbers of accidents as shown in Table 1.

At first, we set a null hypothesis that the occurrence of traffic accidents is dependent on the vehicle types of the two parties, but independent from the combinations of these two parties. Given that hypothesis, we can estimate the expected number of accidents occurring between the two parties as follows;

$$\overline{a}_{ij} = T \frac{y_i}{T} \frac{z_j}{T} = \frac{y_i z_j}{T}$$

where, *i* is a vehicle type of the first (responsible) party. *j* is a vehicle type of the second (affected) party.  $y_i$  is the number of accidents, in which the vehicle type of the first party involved is *i*.  $z_j$  is the number of accidents, in which the vehicle type of the second party involved is *j*. *T* is the total number of accidents.  $\overline{a_{ij}}$  is the expected number of accidents for the combination of the types.

The chi square value for the test of independence is given as follows;

$$\chi_a^2 = \sum_{ij} \left( \frac{a_{ij} - \overline{a}_{ij}}{\overline{a}_{ij}} \right)^2$$

where,  $a_{ij}$  is the observed number of accidents between the two parties *i* and *j*.Comparing this test value with the value of chi-square distribution, we determine that  $\chi_a^2 = 124 > \chi^2(16,0.05) = 26.3$ . The result of this chi-statistic analysis shows a significant interdependence of accident occurrence based on the combinations of vehicle types of the two parties involved. According to the comparison of  $a_{ij}$  with  $\overline{a}_{ij}$ , we find that the numbers of accidents between mopeds (as first party) and large-sized vehicles such as buses and heavy trucks are higher than expected under the independent hypothesis. Similarly, when a small and medium-sized four-wheeler passenger car is the responsible actor, the occurrence rate with mopeds is high.

*Vehicle Type Combinations in Serious and Fatal Accidents.* The second analysis focuses on the seriousness of the accidents categorized by the vehicle type, based on the number of the fatal and serious injury accidents as shown in Table 2.

	Second party (affected)	Passenger car		Cargo/freight		Monada	Subtotal
First party (responsible)		bus	compact & normal	heavy	compact & normal	Wopeus	Subtotal
Passenger car	bus	0	0	0	0	1	1
	compact & normal	0	16	4	10	124	154
Cargo/freight	heavy	0	0	2	3	10	15
	compact & normal	0	5	4	9	56	74
Mopeds		1	35	14	26	13	89
Subtotal		1	56	24	48	204	333

Table 2. Number of serious injury and fatal accidents in Tokyo in 2007

We set a null hypothesis that the seriousness of the accident is independent from the combination of vehicle types. The expected number of serious accidents for each vehicle type combination is calculated as follows:

$$\overline{o}_{ij} = a_{ij} \frac{O}{T}$$

where, O is the total number of serious accidents.  $o_{ij}$  is the expected number of serious accidents for the combination of vehicle types.

The chi square value for the test of independence is given as follows;

$$\chi_o^2 = \sum_{ij} \left( \frac{o_{ij} - \bar{o}_{ij}}{\bar{o}_{ij}} \right)^2$$

where,  $o_{ij}$  is the observed number of serious accidents that occur between two bodies' vehicle types *i* and *j*. Comparing this test value with the value of chi-square distribution, we determine that  $\chi_o^2 = 1579 > \chi^2 (24,0.05) = 36.4$ .

The result shows the statistically significant effects of vehicle type combinations on the seriousness of accidents Specifically from the comparison of  $o_{ij}$  with  $o_{ij}$ , we find that there are many seriously injured persons and fatalities caused by accidents involving buses and trucks, when the moped driver is the responsible actor. Also high numbers of fatalities can be observed in accidents involving mopeds and large-sized vehicle drivers where large-sized vehicle drivers are the responsible party.

# Necessity of Time Dimensional Traffic Management on University Campus

According to the literature review and empirical analysis of accident data collected in

Japan, we have confirmed that the encounter of mopeds and large-sized vehicles have had a significant impact on the occurrence of traffic accidents and the seriousness of accidents. Especially on a university campus, where construction works are going on, a mixture of mopeds and large-sized construction vehicles pose serious challenges for traffic safety.

Considering the difficulty of modal shifts from mopeds to more expensive fourwheelers, we must investigate possible countermeasures in order to decrease the mixture of the two type vehicles in the traffic flow.

We conclude that temporal time dimensional traffic management is required on a university campus, where the moped traffic concentrates prior to the beginning time of classes. Large-sized construction vehicle schedules must be coordinated in avoidance of the peak hours of student commuters using mopeds as a means of transportation.

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