Traffic Safety and Mobility: Reviewing the Ethical Aspects and Revisiting the Definition of Accident Risks

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Abstract: Transport rights and traffic safety are two aspects of transport systems that involve a number of ethical discussions, and though seldom discussed these ethical concerns can be in direct conflict. This study attempts to shed light on this issue by (1) reviewing the ethical discussions on accident risks and the freedom of movement, and (2) redefining accident risks that would be more consistent with the concept of transport rights. We point out the conventional accident risk analysis views travel as just an indicator of exposure, while overlooking the benefit gained from travel. We then redefine the accident risk measure in cost-benefit terms, where accidents are regarded as a cost of obtaining the benefit from travel by all transport modes. Our preliminary empirical analysis shows there are significant differences between conventional and our proposed accident risk measures.

Keywords: Ethics, Traffic safety, Transport rights, Accident risk measure

1. INTRODUCTION

Any kind of social system, including a transportation system, has been developed more or less based on people's ethical judgments at both the individual and organizational level. In the case of risk-related ethical judgments, whether they perceive the risks as voluntary risks or involuntary risks is one of the important elements affecting risk-perception judgments. In general, people are willing to accept risks when they are perceived as voluntary (Starr, 1969; Fischhoff *et al*., 1981), and we basically ascribe responsibility to agents who have had control over their actions (Fredriksen, 2005). In line with this thought, passenger car accidents have been regarded as voluntary risks for which the driver should take responsibility since errors in drivers' decisions ultimately cause accidents, while public transport accidents have been regarded more or less as involuntary risks since passengers are not in control. Of course, changes in the fundamental view of transportation system can cause changes in ethical aspects of accident risks, and such changes have occurred as car has become an indispensable tool for our everyday lives. Particularly, as we will see in the next section, the redistribution of responsibility from drivers to automobile manufactures and governmental sectors has been implemented in developed countries (Wetmore, 2004; Fahlquist, 2006&2007; Evans, 2008). These changes in ethical frames have been reflected in laws and regulations such as the establishment of vehicle safety standards.

The current policy discussions in Japan, particularly the Basic Act on Transport (e.g., Takeuchi, 2012) and transportation deregulation (e.g., Terada, 2004), seem to require further

considerations of the ethical judgments of traffic accident risks. Concretely, though the Basic Act on Transport has not been implemented and the detailed contents have not been fixed yet, it certainly includes discussions on transport rights where people are guaranteed to have a certain level of mobility. One of the restrained interpretations of transport rights, which may be applicable even under the current transportation service level, is that transport rights are considered bundled with the right to choose residential location (Kita, 2012). It is assumed that people basically chose their residential location aware of the transportation service available at that location. In principle they could choose a different residential location with better public transit service and in turn avoid passenger car accident risks.

However, under the condition of transportation deregulation, even such restrained transport rights could not be authorized, because the level of service in the residential location can be easily changed and in turn it becomes practically difficult to choose the residential location with higher level of transit service and in turn avoid accident risks particularly for the future. Thus, if transport rights were authorized under the transportation deregulation, passenger car accident risks would be no longer voluntary risks when the public transport is unavailable, implying the ethical judgments on accident risks should be changed to some extent.

However, to the authors' knowledge, there is little focus on the impacts of mobility related policies on the ethical aspects of accident risks, while there would be an unignorable ethical conflict between traffic safety and mobility. Fahlquist (2009) noted: "There is an inherent tension in the conception of road traffic between the idea of a freedom of movement and an accessible transportation system on the one hand and safety on the other…Those who argue that privacy is merely a prima facie right could possibly argue that safety is a more fundamental value, whereas those embracing a more liberal approach would advocate the value of individual freedom and privacy… What is essentially at issue is how to balance the values of individual liberty and safety (p. 388)". It is noteworthy that such ethical conflict recently has increasingly appeared in the policy discussions: on the one extreme the freedom of movement are going to be enhanced under the right to transport, and on the other extreme accident are going to be eliminated by any means, for example, under the concept of Vision Zero in Sweden (see the next section for details). Analyzing the relationships between these two aspects may be quite important for the subsequent policy decisions, because the decisions such as resource allocation should be made preferentially based on the ethical values and sense of justice held by society (Hokstad and Vatn, 2008).

In this study, by taking the position of traffic safety researchers/practitioners, we attempt to reflect the concept of transport rights into the traffic accident analysis to alleviate the ethical conflict. More concretely, after tracing the ethical discussions on accident risks and the freedom of movement, we revisit the definition of accident risks and argue that, by considering the discussions on transport rights, it is important to employ a comprehensive accident risk measure which focuses on the whole transport system in accident risk analysis, rather than looking at passenger car accident risks solely that the most conventional accident risk analysis focused on. One of the important practical reasons is that conventional passenger car accident risks do not count the accident reduction by promoting public transit. For example, providing age-friendly public transit should be the measure for not only maintaining their mobility, but also reducing accident risks caused by the use of whole transport systems. Such effort is not reflected in the accident risk measures currently used.

This paper is organized as follows. The next section reviews the history of ethical changes in accident risks in the context of Western countries, and then focuses on the changes in Japanese context. After that, we briefly introduce the ethical discussions on transport rights and its conflict with accident risk analysis. In Section 3, we revisit the definition of accident

risks from both conceptual and practical aspects, and attempt to propose an accident risk measure which is less conflict with the concept of transport rights. Section 4 introduces a preliminary comparison analysis between conventional accident risk measures and proposed accident risk measures. Section 5 gives the summary of this study and future tasks. The main contributions of this study are (1) connecting accident risk discussions with mobility-related policy discussions, and (2) proposing an alternative accident risk measure which may be less conflicted with the mobility-related policy discussions.

2. REVIEW ON ETHICAL ASPECTS OF TRAFFIC ACCIDENT RISKS AND THE FREEDOM OF MOVEMENT

2.1 Changes in Ethical Aspects of Traffic Accident Risks

Regarding the changes in ethical aspects of traffic accident risks in United States, Wetmore (2004) gave a nice summary that can be summarized as below.

Since the 1920s, there has been general agreement among governmental sectors, automobile manufactures, safety organizations and insurance companies, that accident issues occur as the result of interaction between driver, vehicle, and road. On the other hand, despite of the agreement, at that time, drivers were considered to be completely responsible for the accident risks.

In 1960s, the first debate was made which was significantly important in the history of traffic safety in terms of the redistribution of responsibilities from drivers to automobile manufactures, resulting in the establishment vehicle safety standards. In other words, the development of technologies designed to compensate for irresponsible human actions officially became a significant component in traffic safety discussions. Wetmore (2004) emphasized that this shift occurred because of the changes of the definition of accident risks. Specifically, the definition was shifted from collision avoidance approach (i.e., how to avoid collision itself) to crashworthiness approach (i.e., the severity of injury), and this conceptual shift of safety put focus on the responsibility of automobile manufactures.

Another important debate was roused especially by the accidents that air bags killed dozens of people in 1990s. The main argument was how governmental sectors and automobile manufactures responded to the failure of technologies which are supposed to compensate for human irresponsibility. Notably, Wetmore (2004) underscored that, despite the fact that they were blamed for killing dozens of people, they successfully defended the necessity and desirability of air bags by redefining the nature of accident risks: The government sectors made clear that the safety system would work well only when each sector carries their duties, for example, when people follow the law such as wearing seatbelts.

There is also another important story that emphasizes the importance of changes in the ethical frames to improve traffic safety: Mothers Against Drunk Driving (MADD), a non-profit organization founded in United States in 1980, has actively worked “to aid the victims of crimes performed by individuals driving under the influence of alcohol or drugs, to aid the families of such victims and to increase public awareness of the problem of drinking and drugged driving (MADD website: http://www.madd.org/)”. Evans (2008) argued that MADD’s activities have culminated in a number of societal and law changes partly as a consequence of making ethical discussions.

On the basis of the facts of American traffic safety history mentioned above, it could be said that the ethical judgments on accident risks, which could be changed by addressing the perceived accident risks of relevant actors (such governmental sectors, automobile

manufactures, and drivers), have played a fundamental role of designing traffic safety related policies. Wetmore (2004) pointed out "those who controlled the precise definition of risk in auto safety had the upper hand in constructing both the solution to the problem and the distribution of responsibilities the solution entailed (p. 377)". In this sense, a special attention needs to be paid to the discussions touching ethical aspects of accident risks.

In this regard, it is worth mentioning that Vision Zero has been launched in Sweden, which is a policy more directly touching the ethical aspects of accident risks. This policy clearly states it can never be ethically acceptable that people are killed or seriously injured during the road travel (Whitelegg and Haq, 2006). Notably, under the concept of Vision Zero, even the freedom of movement is regarded to follow from safety and cannot be obtained at the expense of safety (Tingvall and Haworth, 1999). Vision Zero also introduces the new explicit view of responsibility: "The system designers are invariably ultimately responsible for the design, management and use of the road transport system and thus, they are jointly responsible for the level of safety of the whole system…If the road users fail to abide by the rules…, the system designers must take additional measures to prevent people from dying or being seriously insured (Fahlquist, 2006, p. 1113)". The system designers here are public and private organizations that are responsible for the design and maintenance of road transport system as well as those responsible for different support systems such as rules and regulations, education, rescue work, and care. Though it has not yet been implemented practically, i.e., it hasn't appeared in legal documents (Fahlquist, 2006), the introduction of Vision Zero has stimulated ethical debates on traffic safety (e.g., Elvik, 1999; Fahlquist, 2006; Whitelegg and Haq, 2006). Actually, the similar policies have been adopted in a number of other Western countries. Norway and Denmark have introduced traffic safety policies similar to Swedish Vision Zero (Fahlquist, 2006). Netherlands have introduced the concept of sustainable safety and discussed the responsibility of government (Wegman 2001; Wegman and Wouters, 2002), and the similar discussions have been made in United Kingdom as well (Whitelegg and Haq, 2006).

Like Western countries, the redistribution of responsibilities has been implemented in Japan. One of the first policies causing the redistribution is the Road Transport Vehicle Act (Website: http://law.e-gov.go.jp/htmldata/S26/S26HO185.html (in Japanese)) initially implemented in 1951. This law mainly aims to promote traffic safety by establishing vehicle standards and its management and maintenance rules, indicating some responsibilities have been shifted from drivers to vehicle manufactures/safety organizations. After that, the Traffic Safety Policies Basic Act (Website: http://law.e-gov.go.jp/htmldata/S45/S45HO110.html (in Japanese)) has launched in 1970, aiming at promoting more comprehensive safety policies. Particularly, this policy obliges the government to submit annual report which mentions the current accident conditions, and states 8 actors' responsibilities: national government, local government, organizations who install road, rail, aerodrome and so on, vehicle manufacturing business operators, vehicle users, vehicle drivers, pedestrians, and residents. Especially, it is worth noting that national and local governments have the responsibility of formulating and implementing measures on traffic safety. In more recent years, traffic accidents involving elderly people and children are paid special attention to: The latest White Paper on Traffic Safety in Japan states that, for road traffic, it is necessary more to ensure the safety of vulnerable road users such as children, elderly and physically-challenged people, and policies should be promoted on the basis of such human-oriented philosophy (Japan Cabinet Office, 2012). Considering the above mentioned changes in ethical aspects on accident risks, it could be said that the ethical changes in traffic accident risks in Japan are more or less similar with those in Western countries.

2.2 Freedom of Movement and its Relations with Traffic Accidents

While the policy discussions on transport rights have been made in Japan as mentioned in the Introduction, the movement towards enhancing mobility of vulnerable road users can be confirmed not only in Japan, but also in many Western countries. France is one of the leading countries in terms of ensuring transport rights that were stated in the Law on the Future of Internal Transport in 1982 (Lassave and Offner, 1989). Similarly, by reviewing discussions in United Kingdom from 1960 to 1988, Trinder *et al*. (1991) concludes "most transport debate has been concentrated on issues of formal equity, particularly in relation to the burden of costs, and the meeting of basic needs in relation to transport provision. Equity considerations have become more prominent in transport policy (p. 31)". This kind of tendency is continued, for example, through establishing the Road Traffic Reduction Act 2000 and the Transport Act 2000 (e.g., Hull, 2005). Also in United States, the need for improving public transportation has been clearly stated to enhance mobility for elderly and physically-challenged people, for example, through the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Transportation Equity Act for the 21st Century (TEA-21) in 1998, the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in 2005, and the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012 (Majumdar *et al*., 2013). Thus, looking at the history of mobility-related policies in developed countries, a sort of transport rights has been drawing more and more attention as a fundamental principle of transportation system.

It is noteworthy that, recently, accident risks tend to be discussed associated with mobility-related policies in Japan. This movement is enhanced by the establishment of Act on Promotion of Smooth Transportation, etc. of Elderly Persons, Disabled Persons, etc. in 2006 (Website: http://law.e-gov.go.jp/htmldata/H18/H18HO091.html (in Japanese)). In this regard, for example, a number of projects and researches have been launched to develop safe and conformable vehicles for elderly and to put them to practical use (e.g., Japan Ministry of Land, Infrastructure, Transport and Tourism, 2011; Kuwano *et al*., 2012). These facts indicate that, at least for elderly and disabled persons, traffic safety and mobility tend to be discussed simultaneously to some extent. On the other hand, the conceptual linkage between them has not been well explored, while it could be significant to promote mobility policies in harmony with safety policies, and vice versa. Particularly, the lack of conceptual linkage can be found in the conventional accident risk analysis where only road traffic accident risks are focused on. As we will discuss below, when we consider the linkage, the accident risks of the whole transport system should be considered in the analysis.

From the viewpoint of transport rights, cancelling travel is an inadequate way to reduce accident risks, since the rights that underscore travel are essential for maintaining the minimum standards of living. In other words, transport rights basically view the risks associated with travel as forms of involuntary risks. This implies that it might not be appropriate to analyze passenger car accident risks independently from other transport modes, because we cannot distinguish the reduction of accident risks by "shifting to other travel modes" (which is acceptable from the viewpoint of transport rights) from that by "canceling travel" (which could cause a conflict with the concept of transport rights). Thus, in the light of the recent discussions on transport rights, accident risk analysis should cover the risks of the whole transport system.

From such viewpoint, by more emphasis on transport rights in transportation planning, placing priority on reducing accident risks for road vulnerable users especially those who live in rural areas with poor public transport may be justified to some extent. This is because their accident risks potentially increase more sharply than others' risks when we attempt to ensure a

certain level of mobility. Again, the key point here is to have a more comprehensive view on accident risks that involve risks of whole travel modes. For example, passenger car accident risks may be regarded as voluntary risks in urban areas where a certain level of public transport service are provided, since they can use public transport if they want to avoid the risks. Similarly, the car accident risks may be regarded as involuntary risks in rural areas, since they cannot obtain a certain level of mobility without using car. Therefore, given that the mobility is a kind of right, the availability and service level of other transport modes may determine the nature of passenger car accident risks, i.e., whether the risks are voluntary risks or involuntary risks. However, most existing studies analyzing accident risks have focused only on passenger car accident risks, and the impacts of the above mentioned mobility related policies have little been discussed. As Litman (2013) mentioned, in general, accident risks of public transport is much lower than those of passenger car. And, importantly, he also pointed out "the conventional traffic safety paradigm tends to emphasize strategies for reducing risk per vehicle-kilometer rather than reducing total vehicle mileage". For example, employing strategies for reducing risk per vehicle-kilometer, it might be difficult to capture the impacts of certain types of mobility-related policies on accident risks properly. Suppose that government invests in roads to increase the road capacity and in turn to provide higher mobility by reducing congestion. It is known that smoothing traffic flow can contribute to the reduction of road traffic accident risks (e.g., Sullivan, 1990), while it could increase car use and in turn cancel out the risk reduction by the modal shift. Such rebound effects of mobility related policies could not be captured by the conventional accident risk measure.

3. REVISITING THE DEFINITION OF ACCIDENT RISKS

By considering the above discussions, this section revisits the definition of accident risks. Here, there would be two different types of accident risk analysis: micro-level analysis and macro-level analysis. These two would have different natures: the former focuses on the detailed design of facilities such as intersection and safety technologies for drivers, while the latter focuses on the impact of laws and regulations and a more efficient resource allocation to reduce accident risks, for example. This paper only deals with macro-level accident risks, which are important in national and local governments' public policy debates. For micro-level accident risks, the viewpoints of other stakeholders (such as automobile companies and insurance companies) may also be required, and in this case, the details of accident risks analysis may vary depending on which viewpoint we take.

In this section, we briefly introduce the definitions of accident risks in existing studies, and then attempt to redefine the accident risks which may be more consistent with the concept of transport rights, from both conceptual and empirical viewpoints.

3.1 Definitions of Accident Risks in Existing Studies

The most simple and clear definition of accident risks is "the probability of accident occurrence" (Hauer, 1982), and basically most researches have employed similar definitions. To calculate the probability, we need information on (1) the number of accidents, and (2) the number of trials, i.e., exposure. The detailed specifications of both variables vary across studies (Risk and Shaoul, 1982; Haight, 1986; Chipman *et al*., 1993; Stamatiadis and Deacon, 1997). Haight (1986) mentions that there would be no general agreement on a technical definition of the term "risk". Particularly, the interpretation of the concept of exposure has not been well stated in many existing studies and the quantity is of often difficult to measure

(Chipman, 1982; Hakamies-Blomqvist, 1998). Table 1 shows some major conventional exposure measures that have been empirically used in existing studies. A number of arguments have been made on the selection of exposure measures. For example, although one of the most common exposure measures is kilometers traveled, Risk and Shaoul (1982) point out that this exposure measure still needs to be refined, since interactions between vehicles and roads are not reflected in the distance-based exposure measures. Chipman *et al*. (1993) mention that time-based exposure measures might be better than distance-based measures to explain accident risks among drivers and regions with very different driving patterns and environments.

The existing studies mentioned above focus only on passenger car accident risks. On the other hand, Hakim *et al*. (1991) propose a new conceptual model where accidents are viewed as by-products of obtaining utility from travel. Under their framework, travel is assumed to be generated to obtain utility. Particularly, they stressed that "policies that yield the largest reductions in road accidents are not necessarily the best or most effective policies. The most effective policy is the one that yields the highest net social benefits (p. 380)". This implies that accident risks should be dealt with under the consideration of the benefit of travel.

Table 1. Examples of exposure measures

	Type of exposure	**Examples**
1	Population-based exposure	Population, Number of drivers, etc.
2	Distance-based exposure	Kilometers traveled, etc.
3	Time-based exposure	Car travel time, etc.
4	Trip-based exposure	Number of car trips, etc.

3.2 Redefining Accident Risks: Conceptual Aspects

Although there is no single "best" definition of accident risks, we could select an ethically better one. Of course, the decision of selecting the definition of accident risks may also depend on the purpose of accident risks analysis. In this study, we consider the situation that the accident analysis is implemented for answering macro-level questions such as: which country/city has a better safety transportation system?; which socio-demographic groups can live safer under the current transportation system?; and, how should we allocate a limited budget to regions in a ethically acceptable way?

Next, the meaning of "ethically better" should be identified. In this paper, we assume that a certain exposure measure is "ethically better" than others when it is more consistent with the concept of transport rights where accidents should be basically seen as involuntary risks that are unavoidable costs of obtaining benefit from travel. Also, as mentioned in the previous section, the definition should cover all travel modes because "canceling travel" should not be an option for accident reduction in general under the concept of transport rights.

The next question need to be addressed is what the benefit from travel is. Regarding this, there would be several different viewpoints, but here we employ the fundamental concept of activity-based approach where the benefit of travel is assumed to be activity engagement at destination (Kitamura, 1988). This view might be consistent with the discussions of transport rights because the necessity of transportation rights has been pointed out under the right to live, that is, "All people shall have the right to maintain the minimum standards of wholesome and cultured living (Japan's Constitution, Article 25)". In this sense, when we discuss transport rights, it is important to focus on whether or not people can access necessary facilities such as hospitals and grocery stores, rather than whether people can travel longer or not.

Combining the above mentioned things, accident risks can be seen as a straightforward extension of the concept of Hakim *et al*. (1991), which could be defined as follows:

$$AR = \frac{AC}{BT} \tag{1}$$

where,

AR	: accident risks,
AC	: the number of accidents by all modes, and,
BT	: benefit from travel

This definition can be intuitively understood since it represents a safety level of the whole transport system given the benefit from travel. Actually, such definition of risk is well known as a risk-benefit analysis in the field of risk analysis (Crouch and Wilson, 1982). However, in the field of accident risk analysis, the benefit aspect has been little discussed or has been rudely dealt with. Again, the main reason behind it may be the ethical judgments on accident risks we have employed: accident related policies have independently discussed from mobility-related policies mainly because car accident risks have been basically regarded as kinds of voluntary risks, although responsibilities has been redistributed to some extent. On the other hand, the current policy discussions on transport rights certainly require the focus on the benefit aspect of travel in greater details and seeing car accident risks as involuntary risks. Though measuring the benefit from travel is not simple task, such conceptual shift might need to be reflected in the analysis of accident risks.

3.3 Redefining Accident Risks: Empirical Aspects

In this subsection, we consider the way to reflect the conceptual change of accident risks into the empirical framework. Based on the above conceptual discussions, there would be two important criteria in the quantification of accident risks: (1) it covers all travel modes, and (2) exposure (denominator of eq.(1)) is the benefit from travel. From the empirical viewpoint, observation and approximation problems cannot be avoided. Particularly, measuring the benefit from travel is certainly complicated enough to use a proxy measure. And also required information to cover all travel modes may depend on what kind of approximation we made to measure the benefit from travel. Thus, the question here is which proxy measure is better than others, or, in other words, what kinds of assumptions can be accepted for the calculation of the benefit. In this study, we limit our focus only on the exposure measures listed in Table 1 by considering the data availability. An attempt to find a proxy measure from among conventional measures may be worth in terms of the readiness of empirical application, although further research on the quantification of the benefit is certainly needed.

First, population-based exposure measure requires the assumption that all individuals obtain the same benefit from travel regardless the socio-demographic attributes and the regions they live. Thus, it is clear that this measure does not contain information on the benefit from transport. Second, distance-based (time-based) exposure measure requires the assumption that longer travel distance (travel time) gives higher benefit. This assumption seems to be acceptable to some extent since long-distance travel could increase the possibility to reach the location that provides higher benefit (and travel time can be a proxy measure of distance、though it may include infrastructure condition and congestion rate), but the negative explanation can also be made: people have to travel longer to maintain the minimum standard

living. Thus, this measure is potentially inappropriate since it can be correlated with the benefit both positively and negatively. Finally, trip-based exposure measure requires the assumption that the higher number of trips produces higher benefit, meaning that all trips produce the same benefit regardless of travel distance/time to and activity duration at the destination. Though this assumption doesn't completely capture the actual benefit from travel for example because different destination and different activity purpose may produce different benefit, it is worth mentioning that this measure can be assumed to be positively correlated with benefit from travel: An additional activity at different location may give higher benefit than not engaging in the activity. Actually, the number of trips has been used as a proxy indicator of mobility level (Siren and Hakamies-Blomqvist, 2004). In summary, we consider that trip-based exposure measures may be an appropriate proxy indicator of benefit from travel among the four different types of indicators shown in Table 1, while we should empirically confirm how the selection of exposure measures influences on the quantified accident risks.

4. PRELIMINARY ANALYSIS

This section empirically explores the differences (1) between the conventional risk measures (which focus only on car traffic accident risks) and the proposed risk measures (which focus on the whole travel modes), and (2) between accident risks measuring based on time-based and trip-based exposure measures.

4.1 Data

To implement the comparison analysis, modal share information is needed. Though the modal share information can be obtained from travel diary survey data, such surveys have only been conducted in selected cities. Thus, in this empirical analysis, we quantify accident risks at city level. The data used here is from the 4th Nationwide Person Trip Survey conducted in 2005 by the Japan Ministry of Land, Infrastructure, Transport and Tourism (Japan Ministry of Land, Infrastructure, Transport and Tourism, 2007). In this survey, 62 cities were selected, and responses from about 500 households per city were obtained. We extracted necessary information from the published report. Exposure information was also obtained from the report: As for the conventional exposure measures, we extracted car travel time and the number of car trips, and travel time and the number of trips (for all modes) were obtained as indicators of proposed exposure measures. Distance exposure measures were not available from the report.

For the accident data, because of the data limitation, we only use fatality data in 2005 obtained from Annual Report of Traffic Accident (Institute for Traffic Accident Research and Data Analysis, 2006). Since city-level accident data was available only for selected cities, we focus on 41cities out of 62 cities in the empirical analysis. Note that this accident data contains only road traffic accidents, i.e., bus, private car, two wheels, and walk. Although we had some rail accidents, we assume that the number of accidents is small enough to ignore.

The data used in this preliminary analysis is shown in Table 2 to 4. Table 2 indicates that the number of fatalities per 100,000 population is higher in small and edge cities than in large and central cities. One of the reasons behind this may be the difference of the share of car use as indicated in Table 3: as expected, the share of private car is higher in small and edge cities. Table 4 shows exposure data. Average car travel time and number of car trips are higher in small and edge cities, while average travel time for all travel modes is longer in

large cities. This indicates that choice of exposure measure is crucial in the identification of accident risks.

4.2 Methodology

Accident risks are calculated based on the following equation:

$$AR = \frac{AC}{E} \tag{2}$$

where,

AR	: accident risks,
AC	: the number of fatalities by road accidents, and,
E	: Travel exposure

The third column in Table 2 corresponds to *AC*, and each column in Table 4 corresponds to *E* (more precisely, we use the value multiplied by 365 [day] and population in that area (the second column of Table 2) to make it an annual travel exposure of the area).

4.3 Empirical Results

Calculated accident risks with different accident risk measures are shown in Figure 1. From the figure (a) and (b), the significant difference can be found between conventional risk measures (i.e., exposure by car use) and proposed risk measures (i.e., exposure by all travel modes). Not surprisingly, the differences in accident risks among different cities are much higher when we employ the proposed accident risk measures where the whole transport system is focused on. More concretely, accident risks become high in edge cities in regional urban areas when we employ proposed accident risks, probably because they couldn't use public transport. On the other hand, when we employ the conventional accident risk measures, there are not clear differences across different types of cities. This is because we only focus on the accident risks conditional on car use, i.e., ignoring the availability of other travel modes. Looking at the rankings of accident risks (Table 5), it can be confirmed that there is a substantial difference between proposed and conventional accident risks particularly in the rankings of central cities in three major metropolitan areas: they show the third highest risks based on conventional accident risks, while becoming the lowest risks when we employ the proposed accident risk measures.

Figure 1 (c) indicates that the comparison results between time-based and trip-based exposure measures. It is confirmed that differences in identified accident risks are smaller in trip-based exposure measure, but the difference is not so high, compared to the differences between conventional risk measure and proposed risk measures.

The above-mentioned results clearly indicate that the selection of accident risk measure is critical when we attempt to compare the risks among different cities, which may be needed when we attempt to allocate budget to different cities for improving traffic safety, for example. The selection of accident risk measure is basically dependent on the ethical judgments on what a transportation system should be. As discussed above, under the concepts of transport rights, it is important whether or not a necessary mobility and its benefit can be obtained through the current transportation system. Again, this preliminary analysis results indicate that, to have less contradictory traffic safety debates with the concept of transport rights, we need to look at safety of the whole transport system as a cost of obtaining the benefit from travel.

Table 2. Accident information

	# of selected cities	Total pop. of selected cities	# of fatalities caused by road accidents	Number of fatalities per 100,000 pop.
Central cities in three major metropolitan areas	9	23,341,002	602	2.58
Edge cities in three major metropolitan areas	8	3,037,425	82	2.70
Central cities in regional urban areas [pop.> 1 mil.]	5	6,455,156	213	3.30
Edge cities in regional urban areas [pop.> 1 mil.]	2	393,164	30	7.63
Central cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	6	3,402,073	155	4.56
Edge cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	1	109,084	9	8.25
Central cities in regional urban areas [pop.< 0.4 mil.]	6	1,597,167	72	4.51
Edge cities in regional urban areas [pop.< 0.4 mil.]	2	351,149	22	6.27
Other cities	2	382,065	22	5.76

Notes: (1) City-level accident data was obtained from Annual Report of Road Traffic Accident published by Institute for Traffic Accident Research and Data Analysis. (2) Population data was obtained from National Census in 2005. (3) This table shows data for 2005. (4) The cities focused on empirical analysis were selected based on the data availability of modal share (shown in Table 3) and accident data. The list of cities is shown in Appendix A.

Table 3. Modal share information

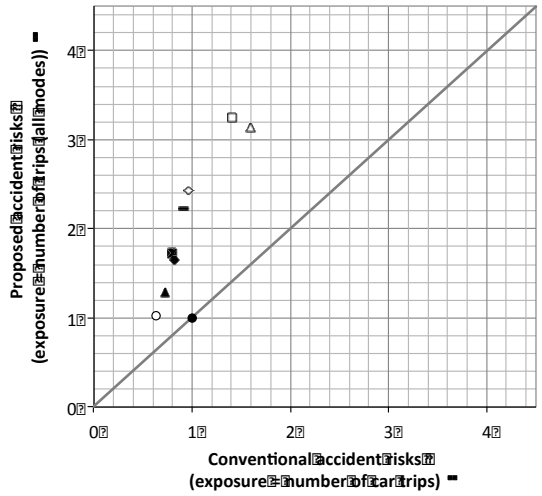
	Rail	Bus	Private car	two wheels	Walk/ Others
Central cities in three major metropolitan areas	26.0%	3.0%	29.3%	18.0%	23.8%
Edge cities in three major metropolitan areas	16.6%	1.6%	47.4%	16.3%	18.0%
Central cities in regional urban areas [pop.> 1 mil.]	8.9%	5.3%	52.5%	13.4%	19.9%
Edge cities in regional urban areas [pop.> 1 mil.]	7.2%	5.6%	57.6%	9.4%	20.3%
Central cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	1.1%	2.1%	63.9%	18.0%	14.8%
Edge cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	2.9%	0.9%	67.6%	13.0%	15.6%
Central cities in regional urban areas [pop.< 0.4 mil.]	2.6%	3.3%	59.2%	18.5%	16.4%
Edge cities in regional urban areas [pop.< 0.4 mil.]	2.9%	1.2%	73.8%	9.7%	12.4%
Other cities	1.5%	0.8%	71.3%	12.8%	13.4%

Notes: (1) Modal share information is obtained from the report published by Japan Ministry of Land Infrastructure Transport and Tourism (2007). (2) Assuming that there are 245 weekdays and 120 holidays, the modal share was calculated based on: (MD*TD*245+ME*TE*120)/(TD*245+TE*120) where MD (ME) is the share of the corresponding travel mode on weekday (holiday), and TD (TE) is the number of trips on weekday (holiday).

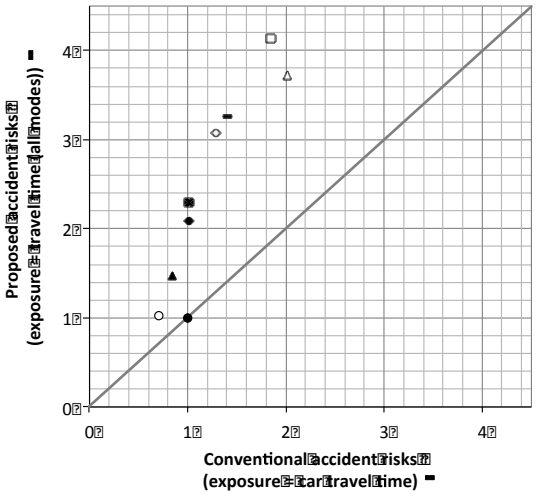
Table 4. Travel exposure (per day)

	Average car travel time	Average number of car trips	Average travel time all modes	Average number of trips all modes
Central cities in three major metropolitan areas	18.89	0.62	60.95	2.10
Edge cities in three major metropolitan areas	28.00	1.02	61.88	2.15
Central cities in regional urban areas [pop.> 1 mil.]	28.80	1.10	52.95	2.09
Edge cities in regional urban areas [pop.> 1 mil.]	27.76	1.14	48.34	1.98
Central cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	32.94	1.37	46.92	2.14
Edge cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	32.69	1.40	47.13	2.07
Central cities in regional urban areas [pop.< 0.4 mil.]	32.73	1.32	51.09	2.22
Edge cities in regional urban areas [pop.< 0.4 mil.]	35.74	1.55	48.16	2.10
Other cities	30.08	1.50	41.64	2.10

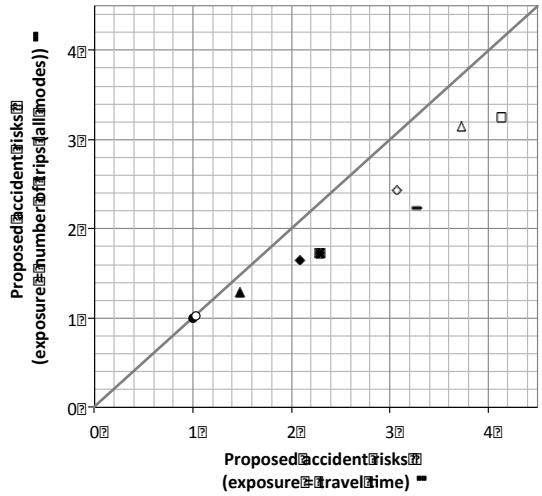
Notes: (1) The information obtained from the report published by Japan Ministry of Land Infrastructure Transport and Tourism (2007). (2) The unit of exposure measures is per person-day. (3) Assuming that there are 245 weekdays and 120 holidays, exposure was calculated based on: (ED*245+EE*120)/365 where ED (EE) is exposure on weekday (holiday).

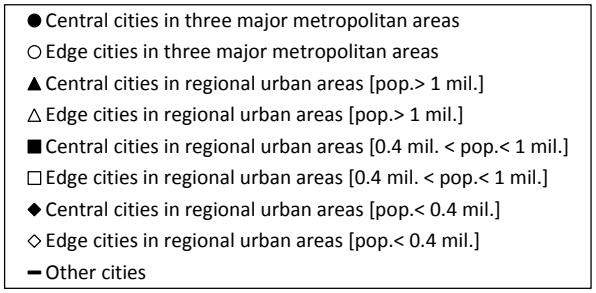


(a) Conventional versus proposed accident risks (Trip-based exposure)



(b) Conventional versus proposed accident risks (Time-based exposure)





(c) Trip-based versus time-based exposures

Note: All accident risks were standardized by accident risks in three major metropolitan areas.

Figure 1. Calculated accident risks with different exposure measures

Table 5. Rankings of accident risks

	Proposed accident risks (exposure = number of trips (all modes))	Conventional accident risks (exposure = number of trips (car))
Central cities in three major metropolitan areas	9	3
Edge cities in three major metropolitan areas	8	9
Central cities in regional urban areas [pop.> 1 mil.]	7	8
Edge cities in regional urban areas [pop.> 1 mil.]	2	1
Central cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	5	7
Edge cities in regional urban areas [0.4 mil. < pop.< 1 mil.]	1	2
Central cities in regional urban areas [pop.< 0.4 mil.]	6	6
Edge cities in regional urban areas [pop.< 0.4 mil.]	3	4
Other cities	4	5

Note: 1(9) means the highest (lowest) accident risks

5. CONCLUSIONS

Mobility and traffic safety are two extreme aspects of transportation system, involving a number of ethical discussions. On the other hand, the ethical conflict between these two aspects in policy decisions has not been well focused on. On the one extreme the freedom of movement is regarded as the secondary purpose of the transportation system which cannot be obtained at the expense of safety as Vision Zero in Sweden indicates, and on the other extreme obtaining a certain level of mobility is a kind of right to keep a minimum standard living as recent debate on transport rights indicates. Although these two extremes have not yet been implemented practically, or even it may be impossible to implement them perfectly at least in short term, these may be basic philosophies indicating the direction of future transport policies. Because of that, more attention needs to be paid to the ethical conflict between these two aspects.

In the conventional accident risk analysis, travel has been basically used as an indicator of exposure to the risks, and the positive aspect, i.e., the benefit from travel, has been overlooked in the analysis. This viewpoint of traffic safety researchers/practitioners could be an obstacle to reduce the ethical conflict between traffic safety and mobility, which is crucially important even for practical discussions: for example, national and local governments have to balance these two aspects to allocate budgets to different measures such as the improvements to road safety facilities and public transit. Thus, in this study, we have tried to reflect the concept of transport rights into the accident risk analysis by (1) reviewing ethical discussions on accident risks and the freedom of movement, (2) redefining accident risks bearing the concept of transport rights in mind, and (3) showing simple comparison results between different accident risk measures. The review results indicated that, while the ethical conflict between them has not been well discussed, the ethical aspects of accident risks and transport rights have basically changed towards emphasizing the two extremes in developed countries. This implies that dealing with the ethical conflict between the two extremes may be of increasing significance.

We have then revisited the definition of accident risks, and argued that accident risks calculated based on the benefit from the whole transport system might be a better measure, which is less conflict with the concept of transport rights. Particularly, accident risks of all travel modes should be discussed simultaneously, because the voluntariness of car accident risks depends on the availability of other transport modes. And, the preliminary analysis results showed that the selection of accident risk measure is crucial in the quantification of accident risks. In summary, we could emphasize the importance of employing exposure measure which covers all travel modes and is based on the benefit from travel, by considering the concept of transport rights.

Though we believe that pointing out the ethical linkage between traffic safety and transport rights is a valuable contribution of this study to revisit the fundamental viewpoint of accident risk analysis, this is still a preliminary study. From analytical viewpoint, how to measure the benefit of travel remains as an important future task. Also, more comprehensive empirical analysis is needed, for example, employing other proxy variables for risk quantification and implementing time-series analysis. It is also worth testing the proposed accident risk measure in other countries. From practical viewpoint, the ethical conflict could be regarded as an issue of institutional design across multiple sectors. Derby and Keeney (1981) mentioned “The heart of the social, political, and ethical complications is the fact that collective action must be taken on risk management alternatives. Critical issues address what process will be used for making the decision and who or what organization should make the decision (p. 223)”. In this sense, how to make a collective decision under the existence of

different policies which give different ethical aspects should be further explored.

ACKNOWLEDGEMENT

This work was supported by Grants-in-Aid for Scientific Research (24-7495). We would like to thank Dr. Junyi Zhang, Hiroshima University, for kindly providing the data used in this paper.

APPENDIX A

Table 4. The list of cities

Three major metropolitan areas (central cities)	Saitama, Chiba, Tokyo, Yokohama, Kawasaki, Nagoya, Kyoto, Osaka, Kobe (9 cities)
Three major metropolitan areas (edge cities)	Tokorozawa, Matsudo, Sakai, Nara, Ome, Gifu, Kasugai, Uji (8 cities)
Regional urban areas [pop.> 1 mil.] (central cities)	Sapporo, Sendai, Hiroshima, Kitakyusyu, Fukuoka (5 cities)
Regional urban areas [pop.> 1 mil.] (edge cities)	Otaru, Kure (2 cities)
Regional urban areas [0.4 mil. < pop.< 1 mil.] (central cities)	Utsunomiya, Kanazawa, Shizuoka, Matsuyama, Kumamoto, Kagoshima (6 cities)
Regional urban areas [0.4 mil. < pop.< 1 mil.] (edge cities)	Komatsu (1 city)
Regional urban areas [pop.< 0.4 mil.] (central cities)	Hirosaki, Morioka, Koriyama, Matsue, Tokushima, Kochi (6 cities)
Regional urban areas [pop.< 0.4 mil.] (edge cities)	Takasaki, Urasoe (2 cities)
Other cities	Joetsu, Imabari (2 cities)

REFERENCES

Chipman, M.L. (1982) The role of exposure, experience and demerit point levels in the risk of collision. *Accident Analysis and Prevention*, 25(2), 475-483.

Chipman, M.L., MacGregor, C.G., Smisley, A.M., Lee-Gosselin, M. (1993) The role of exposure in comparisons of crash risk among different drivers and driving environments. *Accident Analysis and Prevention*, 25, 207-211.

Crouch, E., Wilson, R. (1982) Risk Benefit Analysis. Ballinger Publishing Company, Cambridge.

Derby, S.L., Keeney, R.L. (1981) Risk Analysis: Understanding "How safe is safe enough?". *Risk Analysis*, 1, 217-224.

Elvik, R. (1999) Can injury prevention efforts go too far? Reflections on some possible implications of Vision Zero for road accident fatalities. *Accident Analysis and Prevention* 31, 265-286.

Evans, L. (2008) Death in traffic: Why are the ethical issues ignored?. *Studies in Ethics, Law, and Technology*, 2, Available at: http://www.bepress.com/selt/vol2/iss1/art1.

Fahlquist, J.N. (2006) Responsibility ascriptions and Vision Zero. *Accident Analysis and Prevention*, 38, 1113-1118.

Fahlquist, J.N. (2007) *Moral Responsibility and the Ethics of Traffic Safety*. Royal Institute of Technology, Stockholm, Doctoral thesis.

Fahlquist, J.N. (2009) Saving lives in road traffic: ethical aspects. *Journal of Public*

Health, 17, 385-394.
Fischhoff, B., Lichtenstein, S., Slovic, P., Derby, S.L., Keeney, R.L. (1981) *Acceptable Risk*, Cambridge University Press.
Fredriksen, S. (2005) Luck, risk, and blame. *Journal of Medicine and Philosophy*, 30, 535-553.
Institute for Traffic Accident Research and Data Analysis (2006) *Annual Report of Traffic Accident in 2005*, Institute for Traffic Accident Research and Data Analysis.
Haight, F.A. (1986) Risk, especially risk of traffic accident. *Accident Analysis and Prevention*, 18, 359-366.
Hakamies-Blomqvist, L. (1998) Older drivers' accident risk: Conceptual and methodological issues. *Accident Analysis and Prevention*, 30 (3), 293-297.
Hakim, S., Shefer, D., Hakkert, A.S., Hocherman, I. (1991) A critical review of macro models for road accidents. *Accident Analysis and Prevention*, 23, 379-400.
Hauer, E. (1982) Traffic conflicts and exposure. *Accident Analysis and Prevention*, 14, 359-364.
Hokstad, P., Vatn, J. (2008) Ethical dilemmas in traffic safety work. *Transport Policy*, 46, 1435-1449.
Hull, A. (2005) Integrated transport planning in the UK: From concept ro reality. *Journal of Transport Geography*, 13, 318-328.
Japan Act on Promotion of Smooth Transportation, etc. of Elderly Persons, Disabled Persons, etc. (Japanese law) [URL: http://law.e-gov.go.jp/htmldata/H18/H18HO091.html (in Japanese), accessed on January 5, 2013].
Japan's Constitution [URL: http://www.kantei.go.jp/foreign/constitution_and_government/frame_01.html, accessed on January 5, 2013].
Japan Cabinet Office (2012) White Paper on Traffic Safety in Japan 2012 [URL: http://www8.cao.go.jp/koutu/taisaku/index-t.html, accessed on January 28, 2013] (in Japanese)
Japan Ministry of Land, Infrastructure, Transport and Tourism (2007) Travel behavior in Japanese cities [URL: http://www.mlit.go.jp/crd/tosiko/zpt/pdf/h17zenkokupt_panf.pdf, accessed on February 3, 2013] (in Japanese).
Japan Ministry of Land, Infrastructure, Transport and Tourism (2011) A report on the demonstration experiments of utilizing personal mobility [URL: www.mlit.go.jp/common/000172087.pdf, accessed on February 7, 2013].
Japan Road Transport Vehicle Act (Japanese law) [URL: http://law.e-gov.go.jp/htmldata/S26/S26HO185.html (in Japanese), accessed on January 5, 2013].
Japan Traffic Safety Policies Basic Act (Japanese law) [URL: http://law.e-gov.go.jp/htmldata/S45/S45HO110.html (in Japanese) , accessed on January 5, 2013].
Kita, H. (2012) Basic Act on Transport and local public transport plan. *IATSS Review*, 37(1), 32-40 (in Japanese).
Kitamura, R. (1988) An evaluation of activity-based travel analysis. *Transportation*, 15, 9-34.
Kuwano, M., Okada, Y., Chikaraishi, M., Fujiwara, A. (2012) Analysis on promoting factors of Personal Mobility considering social network, *Proceedings of Infrastructure Planning*, Vol. 45, CD-ROM (in Japanese).
Lassave, P., Offner, J.M. (1989) Urban transport: changes in expertise in France in the 1970s and 1980s. *Transport Reviews*, 9, 119-134.
Litman, T. (2013) Safer than you think! Revising the transit safety narrative. Paper presented at the 92th Annual Meeting of the Transportation Research Board, January 13-17, 2013, Washington D.C.
Majumdar, S.R., Sen, L., Park, S. (2013) The feasibility of mobility management in the

United States. *Public Works Management and Policy* (In Press).
Risk, A., Shaoul, J.E. (1982) Exposure to risk and the risk of exposure. *Accident Analysis and Prevention*, 14, 353-357.
Siren, A., Hakamies-Blomqvist, L. (2004) Private car as the grand equaliser? Demographic factors and mobility in Finnish men and women aged 65+. *Transportation Research Part F*, 7, 107-118.
Stamatiadis, N., Deacon, J.A. (1997) Quasi-induced exposure: Methodology and insight. *Accident Analysis and Prevention*, 29, 37-52.
Starr, C. (1969) Social benefit versus technological risk: What is our society willing to pay for safety? *Science*, 165(3899), 1232-1238.
Sullivan, E. (1990) Estimating accident benefits of reduced freeway congestion. *Journal of Transportation Engineering*, 116(2), 167-180.
Takeuchi, K. (2012) Basic Act on Transport, *IATSS Review*, 37(1), 4-5 (in Japanese).
Terada, K. (2004) A Study of the Deregulation Consequences: Local Bus Market, *IATSS review*, 29(1), 52-60 (in Japanese).
Tingvall, C., Haworth, N. (1999) Vision Zero-An ethical approach to safety and mobility. paper presented to the 6th International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne, Australia, 6-7 September 1999 [http://www.monash.edu.au/muarc/reports/papers/visionzero.html, accessed in January 2013].
Trinder, E., Hay, A., Dignan, J., Else, P., Skorupski, J. (1991) Concepts of equity, fairness, and justice in British transport legislation, 1960-88. *Environment and Planning C*, 9, 31-50.
Wegman, F., Wouters, P., (2002) Road safety policy in the Netherlands: facing the future, . SWOV Institute for Road Safety Research, The Netherlands, Leidschendam.
Wetmore, J.M. (2004) Redefining risks and redistributing responsibilities: Building networks to increase automobile safety. *Science, Technology & Human Values*, 29, 377-404.
Whitelegg, J., Haq, G., (2006) Vision Zero: Adopting a target of zero for road traffic fatalities and serious injuries. The Department of Transport, DfT Horizons Programme.