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The non-linearity of risk and the promotion of environmentally sustainable transport

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ABSTRACT

Several studies show that the risks of injury to pedestrians and cyclists are highly non-linear. This means that the more pedestrians or cyclists there are, the lower is the risk faced by each pedestrian or cyclist. On the other hand, the more motor vehicles there are, the higher becomes the risk faced by each pedestrian or cyclist. The relationships found in previous studies suggest that if very large transfers of trips from motor vehicles to walking or cycling take place, the total number of accidents may be reduced. The "safety in numbers" effect for pedestrians and cyclists would then combine favourably with the effect of a lower number of motor vehicles to produce a lower total number of accidents. This paper explores if such an effect is possible, relying on the findings of studies that show the non-linearity of injury risks for pedestrians and cyclists. It is found that for very large transfers of trips from motor vehicles to walking or cycling, a reduction of the total number of accidents is indeed possible. This shows that the high injury rate for pedestrians and cyclists in the current transport system does not necessarily imply that encouraging walking or cycling rather than driving will lead to more accidents.

1. Introduction

Increasing concern about global warming and environmental degradation has lead to a heightened interest in how best to promote environmentally sustainable transport. While the amount and forms of motorised transport that can be regarded as environmentally sustainable remains a topic for discussion, hardly anyone would dispute a claim that walking or cycling are environmentally sustainable modes of transport. Walking or cycling does not pollute, requires much less space than any form of motorised transport, and is associated with public health benefits. One way of promoting environmentally sustainable transport would therefore be to encourage walking and cycling, in particular if more walking or cycling is associated with a corresponding reduction in the use of motorised transport.

However, concerns about road safety would seem to represent an important argument against encouraging walking or cycling. These modes of transport are associated with a considerably higher risk of injury accidents than travel by car or bus. Fig. 1 shows injury rates per million kilometres of travel for Norway for various modes of travel during 1998–2005 (Bjørnskau, 2003, 2008; Rideng and Vågane, 2008). These injury rates are based on police reported injury accidents and estimates of the amount of travel based on travel behaviour surveys. The pattern seen in Fig. 1 is typical of many highly motorised countries. It is seen that the risk of injury when walking is about 4 times higher than when driving a car. The risk of injury when cycling is about 7.5 times higher than for car occupants. If more people walk or cycle, one would therefore, all else equal, expect there to be more injuries.

It is essential to keep in mind that the differences in injury risk shown in Fig. 1 represent the current modal split between the various modes of transport. Risks are not necessarily constant if modal split changes—if, for example, more people walk or cycle and fewer people drive. An increasing number of studies, reviewed in the next section, show that the risks of injury to pedestrians or cyclists are highly non-linear. The non-linearity of risk implies that, all else equal: (1) the more pedestrians or cyclists there are, the lower becomes the risk to each pedestrian or cyclist, and (2) the more motor vehicles there are, the higher becomes the risk to each pedestrian or cyclist. Hence, pedestrians or cyclists face a high risk if they are few in number and mix with a high number of motor vehicles. On the other hand, if pedestrians or cyclists are more numerous, and there are fewer motor vehicles, the risks faced by pedestrians or cyclists are comparatively low. This suggests that by getting car drivers to walk or cycle, walking or cycling would become safer and there would not necessarily be an increase in the number of road traffic injuries proportional to current levels of risk.

In fact, depending on the shape of the non-linearity of risk, it is even conceivable that a large transfer of trips from motor vehicles to walking or cycling would be associated with a reduction of the

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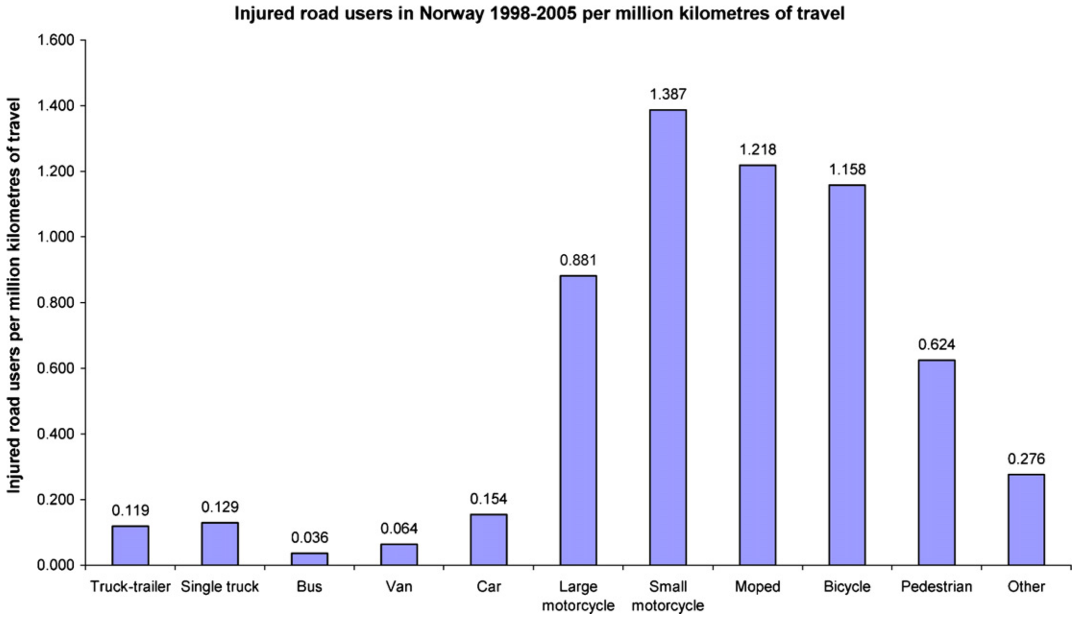

Fig. 1. Injured road users per million kilometres of travel in Norway 1998–2005. Sources: see text.

number of accidents. The main objectives of this paper are: (1) to explore if such an outcome is possible and (2) gain an impression of the size of the transfer of trips from motor vehicles to walking or cycling that is needed in order to pass the "tipping point" at which the combined benefits of "safety in numbers" for pedestrians or cyclists and a reduced number of motor vehicles lead to fewer accidents.

2. Literature review

A number of recent studies have shown that the risks of injury to pedestrians or cyclists are non-linear, that is they depend on the number of pedestrians or cyclists. All these studies have found that the risk faced by each pedestrian or cyclist declines as the number of pedestrians or cyclists increases. This has been labelled the "safety in numbers" effect. Table 1 reviews recent studies that have found a "safety in numbers" effect for pedestrians or cyclists.

The studies listed in Table 1 are those that have been quoted most frequently in recent years. No claim is made that the studies included in Table 1 are exhaustive. For the purpose of this paper, however, it is not essential that the studies reviewed are all those that have ever been made. Should it be the case that the list of studies in Table 1 is incomplete, and the missing studies have produced findings suggesting that there is no safety in numbers effect, it would be easy to revise the simple model estimates developed in this paper.

Most of the studies listed in Table 1 have developed accident prediction models for pedestrian or bicyclist accidents of the following general form:

$$\text{Number of accidents} = \alpha Q_{MV}^{\beta_1} Q_{PED}^{\beta_2} \quad (1)$$

In this equation, Q_{MV} and Q_{PED} represent the volume of motor vehicles and the volume of pedestrians (Q_{CYC} is the volume of cyclists), often indicated by the annual average daily traffic (AADT), α, β_1 and β_2 are coefficients that are estimated. The coefficient α is a scaling parameter, which ensures that the predicted number of accidents is in the same range as the recorded number of accidents. Coefficients β_1 and β_2 describe the shape of the relationship between traffic volume and the number of accidents. As shown by the studies listed in Table 1, either coefficient often takes on a value between about 0.3 and 0.9. The sum of the two coefficients tends to be greater than 1. Briefly speaking, this means that: (1) the risk to each pedestrian or cyclist declines as the number of pedestrians or cyclists increases, (2) the risk to each motorist of striking a pedestrian or cyclist declines as the number of motor vehicles increases, and (3) the risk to each pedestrian or cyclist increases as the number of motor vehicles increases. This suggests that if there is a large transfer of trips from motor vehicles to walking or cycling, it is in principle conceivable that the number of accidents could decline.

3. Model estimates of the expected number of accidents

3.1. Exploratory analysis of model parameters

Based on the studies shown in Table 1, an exploratory analysis has been performed for the purpose of determining whether certain transfers of trips from motor vehicles to walking or cycling are associated with a reduction in the total number of accidents. The total number of accidents includes not just accidents involving pedestrians or cyclists, but also accidents involving motor vehicles only. To model the relationship between the number of motor vehicles and accidents involving motor vehicles only, recent accident models (Fridstrøm, 1999; Taylor et al., 2002) and reviews of such models (Eenink et al., 2007; Reurings et al., 2006) were studied. The shape of the relationship between the number of motor vehicles and the number of accidents varies depending on the type of accident. Broadly speaking, a distinction can be made between multi-vehicle accidents (rear-end, head-on, junction accidents) and single-vehicle accidents. The following functional relationships were chosen for these accidents:

$$\text{Multi-vehicle motor vehicle accidents} = \alpha Q_{MV}^{1.05} \quad (2)$$

$$\text{Single-vehicle motor vehicle accidents} = \alpha Q_{MV}^{0.80} \quad (3)$$

The relationship in Eq. (2) implies that the number of multi-vehicle accidents involving motor vehicles only increases slightly more than proportional to the number of motor vehicles. The relationship in Eq. (3) implies that the number of single-vehicle accidents involving motor vehicles only increases less than proportional to the number of motor vehicles. It is assumed that the total number of accidents is equal to the sum of multi-vehicle motor vehicle accidents, single vehicle motor vehicle accidents, accidents