Internalisation Policies for Road Transport Safety Externality

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Abstract:

In an optimal pricing system road users should bear the marginal social cost of their travel. The main problem is that it is not possible to identify the producers of these costs in advance to charge them a price for their travel. All trips are associated with certain risks of accidents. In addition, there are traffic law offenders whose risk taking behaviour generates social costs to all road users as well as to other members of society. The paper identifies the issues and analyses the possibility of internalising some of the costs through a pricing system. It also discusses the options for minimising the social costs which cannot be internalised by a pricing system due to the problem of non-identification before the actual occurrence of social costs.

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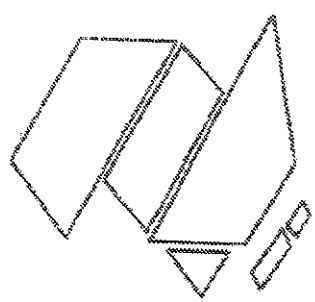


1. INTRODUCTION

In an optimal pricing system road users should bear the marginal social cost of their travel. This includes direct as well as externality costs. Road users meet the direct costs. The externality costs are those that are not met directly by the users. These include costs of congestion, pollution and traffic accidents. This paper concentrates on the internalisation of the marginal costs of accidents external to the road user.

If there were no traffic on the road there would be no accidents. Even if there is only one vehicle on the road there is a risk of an accident. This risk depends on several factors: driver quality, road quality, weather conditions, vehicle safety standard, driving speed etc. Excepting the weather conditions, we have some control on all other factors. An accident/crash may occur due to a failure of any of these factors.

Transportation literature has, in recent years, started differentiating between accident and crash. It is argued that in an accident the user has no control, whereas a crash is caused by factors which can be controlled and therefore is avoidable. This distinction is important in the present context. The differentiation in a real life situation is, no doubt, difficult. I shall start with no distinction, but will come back to it at a later stage in the paper.

This paper differentiates between the social costs of accidents and crashes and discusses the feasibility of internalising the social costs in each case.

2. CONSTRAINTS OF INTERNALISATION

Each trip produces risks of accidents to the driver and other vehicle occupants as well as to other road users. It can be assumed that rational drivers consider the risk to themselves and to other vehicle occupants as part of their generalised costs. The risk imposed on others is an externality. The externality cost is, to some extent, internalised through taxes (road prices) by making it part of the generalised cost. At the optimal level this tax should be equal to the marginal cost of risk imposed on other road users as well as other members of society. The non-road users also suffer from the pain and grief caused by the loss of life and life quality of close relatives. In addition, they bear part of the costs of medical treatment and rehabilitation depending on the public health system in the country.

Identification Problem

The risk imposed on others varies from driver to driver and it cannot be pre-determined in most circumstances. It is, however, identifiable, to a certain extent, at a cost. While on patrol, traffic police intervene when they observe any abnormal driving or detect high level of intoxication in random checks. Once this abnormality is noticed, the risk can be reduced by removing the driver from the road. The cost function for detecting this risk generating behaviour is likely to be a steeply rising

function beyond a certain point. It is, therefore, not practicable to remove the risk altogether. As the level of enforcement increases, not only some offenders are taken out of the road, but also others get discouraged by the high prospect of being apprehended. Thus risks imposed by drivers on themselves as well as on others are functions of the level of traffic law enforcement, but the reduction possibility is constrained by the steeply rising cost function.

Traffic Law Offenders and Enforcement

A user pay or price for road services system is an instrument for internalisation of externalities, if externalities are identified in advance as mentioned above. Another common instrument is regulation which specifies rules for driving and vehicle and infrastructure standards. Enforcement and fines are applied to ensure compliance with regulations. Fines are imposed on violaters of regulation when they are identified. Both price and fine are monetary payments. Price is paid to buy a service, while fine is paid by an offender to compensate for the harm or potential harm to society caused by the offence. Both these instruments have internalisation effects, but they work differently. A price for road safety services increases the cost of travel and so has an impact on the demand for travel. A fine may also have an effect on the demand for travel, (eg. fine for driving a non-safe vehicle), if the probability of being apprehended while violating the traffic regulation is high. In many instances of traffic offences, a fine does not affect the demand for travel, for example a fine for speeding or for drink driving. In conjunction with enforcement, it is expected to have an effect on the demand for offences.

Traffic safety regulations must be enforced to make them effective. In the absence of enforcement, regulatory conditions are observed only by those who strongly value those conditions for their own safety, and those law-abiding individuals who find it immoral to do otherwise. While a large proportion of the population may belong to this category, safety enforcement is necessary mainly because there exist other types of individual who would not follow the regulations if they were not enforced. The effectiveness of any set of regulations depends on the resources used for enforcement and the efficiency with which they are used. It depends on the deterring ability of the enforcement mechanism.

Vehicle drivers can be grouped into two categories: law abiders and offenders. Law abiders are those who drive within the legal limits. Offenders are responsible for major crashes. In New Zealand, for example, about 60% of all road deaths are caused by high speed driving and/or drink driving The possible instruments for reducing this cost to society would be those which have impacts on society's attitude towards these behaviours (publicity campaign and education for example) and enforcement so that the probability of apprehension is high.

Traffic offenders can perhaps be divided broadly into two categories: impulsive offenders and others. Impulsive offenders act without any pre-determination and thus their behaviour may not be responsive to any enforcement measures.

Enforcement nevertheless will be effective in apprehending them. The others are expected to be deterred from committing offenses by the probability of apprehension and the level of punishment. The level of punishment may not be effective for the impulsive category.

Probability of Apprehension and Punishment

These two factors, viz. the probability of apprehension and the level of punishment determine the expected punishment for committing an offense. An offender is punished only when the person is identified and proven to be guilty. How these factors will affect their behaviour depends on the nature of the offender. Following Becker (1968), offenders can be further categorised into three groups by their risk taking attitude: risk neutral, risk averse and risk preferrer. To a risk neutral person, both factors have the same effects, if there is no change in the expected cost of punishment. Assuming that a person's utility depends on the level of wealth, and punishment is equivalent to a loss of wealth or income, the level of utility remains the same for a risk neutral person as long as the expected cost of punishment is the same. In such a case, if the probability of apprehension increases, but it is compensated by lower punishment so that the expected value of punishment remains the same, the person's utility remains unchanged. If the person is a risk preferrer, in the same situation although the expected cost of punishment remains unchanged, the utility is reduced. To a risk preferrer the success in taking the risk is important. Since the increase in probability of apprehension reduces this success rate, the level of utility is reduced. The opposite happens to a risk averse individual. Since the probability of apprehension is more effective than the level of punishment expected when apprehended, as observed by Becker (1968) for crimes in general, the traffic offenders are likely to be dominated by risk preferrers.

In most circumstances of traffic offences, the offender is fined when apprehended by a traffic police. However, in some severe violations, the offenders are imprisoned and/or suspended from driving. In such cases, further resources are needed to execute the punishment. An offender presumably gains from the undetected offenses, eg, time saved from driving at a speed higher than the prescribed limit. The net damage to society is the total damage done by the offender including self injuries, if any, in excess of the benefits gained from the offense. Thus, as suggested by Becker (1968), society suffers from three types of costs: (i) the net damage done by the offenders (ii) the costs of enforcement and (iii) the costs of executing punishments.

As far as the punishment level is concerned, the offender must compensate for the harm done to society and the cost of apprehension and conviction. Becker (1968) suggests that an optimal fine should be equal to the sum of the marginal cost of harm and the marginal cost of catching and convicting the offender.

The probability of apprehension has negative impact on the level of traffic offence. This probability increases with the level of enforcement and appropriate

enforcement strategies. If it is assumed that the risk to oneself is included in the generalised cost function of the rational driver, then the external costs can be categorised into costs arising from (a) inherent factors and (b) factors controllable by enforcement. The first cost component is part of the driving process and cannot be reduced through enforcement. These can be termed accident costs. It may be possible to reduce these costs through road improvements and improvements in driving and vehicle safety standards. The marginal external cost of a crash caused by an offender is this inherent marginal external cost of the road transport system plus the additional marginal cost generated by the risk taking behaviour.

3. OPTIMAL CONDITIONS

The social cost of a trip consists of the following:

1. The cost incurred by the person and
2. The cost imposed on other road users.

A rational trip maker will equate marginal benefit of the trip to the marginal cost incurred by him/her. The cost incurred by the person consists of

a. The operating cost
b. The expected cost of accidents/crashes to the trip maker including expenses as well as pain and suffering caused by injuries.
c. The cost of time

Part of the second cost component (b) is caused by the risk taking behaviour of the person. Let us suppose the person is well aware of these costs and his/her decision of making the trip is based on the selfish attitude. In that case, the trip will be made if and only if a+b+c is less than or equal to the marginal benefit the person receives from the trip. The marginal benefit includes the pleasure obtained from the act of offence (eg, pleasure of driving at high speeds and the value of time saved).

The gap between the marginal benefit and the marginal social cost is the cost imposed on other road users. As explained earlier this cost has two components and can be expressed as

$SCO_i = \alpha + O_i(E)$

where,

SCO_i is the cost imposed on others by trip maker i
α is constant for all trips for a type of vehicle and
$O_i(E)$ is the cost imposed on others which is a function of the level of traffic enforcement (E).

α is the inherent cost of the trip on which the level of enforcement (E) has no effect. The reason for separating out these two cost categories is that part of the cost imposed on others i.e, α does not depend on the law abiding behaviour of the trip maker. A large portion of the other part (O), which is a function of the driving

behaviour, can be controlled through traffic enforcement.

The Level of Enforcement

If the driving behaviour of an offender is observable and pre-determined, the optimal tax should be equal to O_i provided of course the rest of society is willing to exchange the additional risk with wealth This will depend on the property right assignment considered optimal by society.

If individuals cannot be identified by the risks they produce before either an accident has occurred or the person is apprehended by the traffic enforcement officers, the tax cannot be varied by the level of risk they impose on others. As a result of this, the pricing policy is constrained by charging the same tax to all vehicle drivers for the same trip. If the same tax is imposed on both offenders and law abiders there will be inefficiency as well as inequity. It will be inequitable because the law abiders will bear the same cost as the risk producing offenders even though they are not responsible for a major portion of the resulting social costs. If an accident tax is imposed to recover the monetary cost of accidents/crashes, then the same tax on both groups means that the risk producers are subsidised by the law abiders. As a result, cost paid for a trip by a law abiding vehicle driver will be higher than the social cost of producing that trip but it will be lower for a road user producing extra risks of death, injuries and property damage to others. Therefore, the system will encourage higher number of trips by offenders and lower number of trips by law abiders. Clearly there will be inefficient production of trips. It will increase the production of high risk trips and reduce the production of low risk trips. Thus it does not serve the purpose of imposing the accident tax.

Offenders are the people responsible for major crashes causing heavy social costs. While it is true that their risk taking and risk producing behaviour is influenced more by the probability of apprehension than the amount of fine when apprehended, both factors are important as shown in a different context by Kooreman (1993). The probability of apprehension depends on the level of enforcement. The social cost depends on the rate of offence.

Let R = Rate of offence i.e, number of offences per unit period
π = Probability of being apprehended when an offence is committed
f = Fine imposed on the offender per proved offence
C = Expected social cost per offence
$C1$ = Expected social cost per offence to others
$C2$ = Expected value of costs incurred by offender per offence
E = Level of enforcement expressed in dollars

Both the rate of offence and the probability of apprehension are functions of the level of enforcement (E). Therefore,

$$R=R(E,f) \quad \frac{\partial \pi}{\partial E} \geq 0 \quad \frac{\partial R}{\partial E} \leq 0 \quad \frac{\partial R}{\partial f} \leq 0$$
$$\pi=\pi(E)$$

The marginal reduction in social cost per unit change in enforcement is given by

$$MSE = -\frac{\partial R}{\partial E} C$$

At the optimal level the marginal reduction in social cost of an offence through enforcement should be equal to the marginal cost of enforcement.

The expected social cost of an offence is the expected social cost of the loss of life and life quality and the resource costs required due to accidents occurring as a consequence of the offence. It is difficult to determine the social cost of accidents in monetary terms, since it requires the valuation of the loss of life and life quality. One way to value this is to determine the amount of money that society would be willing to exchange for a reduction in the risk of accidents. In that case following Jones-Lee (1989), C can be interpreted as the average value of marginal rates of substitution of wealth for risk of accidents resulting from the offences. The social welfare is maximised when the marginal cost of risk reduction equals the willingness to pay value of the risk reduction. The value of C can be estimated once the values of statistical life and life quality are established following the willingness to pay approach.

Such studies have been carried out recently in New Zealand (Miller and Guria 1991, and Guria 1993) and in the U.K (Jones Lee et al 1985 and O'Reilly et al 1992). When the willingness to pay values of accident risk reductions are used to determine the value of C, the minimisation of social costs become equivalent to maximisation of the net social benefit. If E is expressed in dollars, then at the optimal level MSE should be equal to 1.

The Level of Fine

The fines can be determined either as a means of recovering the social cost imposed by the risk producing offenders or as an instrument for minimising the social cost or both. The expected cost to the offender is $R\pi f + RC2$ per year. The expected social cost per year is RC.

Thus, $R\pi f + RC2 = RC$
or, $R\pi f = RC1$

The expected cost of fine should be equal to the average social cost of the offence. Therefore, f should be equal to $C1/\pi$. Thus the fine should be equal to the expected social cost per apprehended offence. It should, however, be noted that if the scheduled fine is very high, it is seldom imposed by the court. This constraint

needs to be incorporated in the optimisation process. π is a function of E and MSE is a function of f. The optimal values of E and f should be determined from these two simultaneous equations.

The probability of apprehension is a very important factor. This influences the probability perceived by potential offenders which is expected to have an impact on their behaviour. As mentioned earlier, the level of fines has an impact on the behaviour of offenders if the probability of apprehension is high. As noted by Kooreman (1993) in the context of fare evasion in public transport, there exists heterogeneity in the risk aversion or preference behaviour of the offenders. Given the heterogeneity, Kooreman (1993) observes that as the probability of apprehension increases, so does the offenders' average perceived probability. This is expected to reduce the rate of offence.

It becomes more complicated when other forms of punishment are considered. There are both advantages and disadvantages with each form of punishment. Fines are very commonly used particularly in traffic offences. However, loss of driving license and imprisonment are also used in some severe offence cases. The main advantage with a fine is that it does not cause any resource cost other than the cost of collection of the fine. It is a transfer from an individual to society and hence there is no social cost. The main argument against it is that this amounts to allowing an offender to buy the right to offend in exchange of money. The second argument is that in some cases, the harm done to society is so large that no amount of money can compensate for the loss. Even where the harm can be measured by a finite amount of money, the existing wealth of the offender may not be sufficient. As observed by Shovel (1987), an offender's potential of doing harm is great in relation to his/her asset. The question that arises in this case is: should the offender be punished with imprisonment or some other punishment in such a situation? A severe punishment is expected to reduce the propensity of committing offences. That is a gain to society. But in most such cases, there are external costs. For example, in case of imprisonment, the prison costs are borne by society. Thus even the victim, if alive, shares the cost instead of being compensated for the damage. There is a problem of equity. There is no obvious solution to this problem. The optimal strategy and instruments, it appears, will have to be determined under this constraint.

Welfare Loss to the Offender

Since fine is not a cost associated with each trip, it can be assumed that it will not have any impact on the number or length of trips by the offenders. However, some of them get pleasure in driving at high speed or drinking before driving. Increase in enforcement level and high fines are aimed to restrain these behaviours. This will reduce their overall utility. While this is true, it should not be part of the total social welfare function. The development of traffic rules and regulations means that these are criteria for allocating the property rights of the collectively owned resources - the road space. Those, who violate the rules and regulations, reduce the

property rights of others to increase their own property rights. This is equivalent to stealing. The increase in their welfare resulting from this illegal activity should, therefore, be outside the social welfare function.

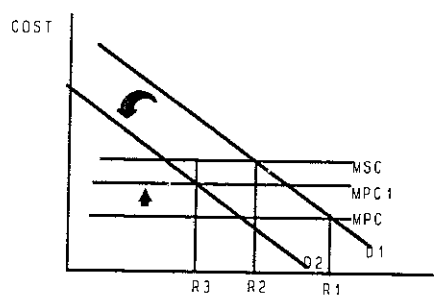
Effects of Enforcement on the Offence Rate

As mentioned earlier, the optimal level of enforcement is one at which the marginal saving in social cost is equal to the marginal cost of enforcement. Now let us look at the behaviour pattern of offenders with respect to enforcement and fine which will lead to the optimal situation.

To an offender the cost of committing an offence is the expected cost of punishment. It is the fine or imprisonment or some other form of punishment when the offender is caught and it is nothing at other times, excepting cases where the offender suffers personal losses resulting from the offence. If the cost of this is higher than the utility he/she receives from committing that offence, then it is expected that the offender will not commit such an offence. Impulsive offenders are exceptions.

Consider fig. 1. In this diagram the marginal benefits received by offenders is shown by demand for offences D1. The cost incurred by an offender is the expected costs of property damage, fine and injury per offence. It is assumed that as cost increases less number of offenders will be committing offences. Therefore, the demand for offences by offenders will have the usual downward sloping curve. The marginal private cost is shown by the line MPC. It is drawn as a horizontal line under the assumption that the cost incurred per offence of a given type does not change with the number of offences committed. It would be upward rising if fines increased for previous convictions. The marginal social cost per offence is the expected cost incurred by society including those suffered by the offender. For a given type of offence it can be

Fig 1: Effects of the level of enforcement on the rate of offence



assumed that the marginal social cost per offence is constant. This is the marginal social cost of accident per offence. The cost of enforcement is not included in this.

Offenders are expected to equate their marginal private benefits with marginal private costs. Thus at equilibrium the number of offences will be R1. There is a gap between the marginal social costs and benefits. There is no difference between marginal private and social benefits, since no body other than the offender receives any benefit from the offence.

An increase in enforcement level will increase the probability of apprehension. This will reduce the demand for offences at each level of fine (or some other form of punishment). Since offenders are expected to be dominated by risk preferrers, even when the expected fine per offence is unchanged, the demand curve should shift to the left. At a given level of fine, as the probability of apprehension increases, so does the expected fine per offence. This increases the marginal private cost. Suppose D2 and MPC1 are the demand and marginal private cost lines at the optimal level of enforcement. Then R3 is the optimal rate of offence. In fig. 1, R3 < R2. However, it is not a requirement or a necessary condition of the optimal level. The position of R3 will depend on the marginal effects of the probability of apprehension on the demand for offences.

4. POLICY OPTIONS

The economic theory suggests that the expected cost of fine or any other form of punishment to the offender should be equal to the marginal social cost of the offence. If the fine is higher, there is a net welfare loss to the offender. If the fine is lower, there is a net welfare loss to society. Unfortunately the problem is much more complex. The fact that some offenders die or become severely disabled as a result of the offence, they would not be able to pay the compensation for the social cost caused on other members of society. Instead they might even impose additional cost to society in terms of their long term medical treatments and financial social benefits paid to them. Another serious limitation is that the apprehended offender may not have the wealth or the ability to pay the fine. If the scheduled fine is high, it has been observed that the judges are reluctant to impose that fine on the offender in most circumstances. This is further constrained by the society's responsibility to other members of the offender's family.

The obvious question is what should be done in these circumstances? The level of fine should be such that it is enforceable. Thus the total fine revenue is likely to be lower than the total social cost of offences.

Let us first look at the social costs of accidents. These are inherent costs of the transportation system. Therefore, the costs to be recovered through a pricing/tax system should depend on the cost sharing principle of the society. Under the current ACC system in New Zealand, for example, the victims are partly compensated by the ACC. The rest of the cost is borne partly by society (for example, public

hospital treatments) and partly by the victims themselves. The cost sharing principle should be independent of determining the optimal level of preventive measures.

The willingness to pay estimate of these costs indicate that the social welfare improves through exchange of wealth for risks of accidents as long as the marginal social cost saved is higher than the cost of preventive measures. Even though these are inherent costs of a given transport system, the costs can be reduced in many situations through improvements in the infrastructure. The optimal level of these preventive measures will be one at which the marginal social benefit is equal to the marginal social cost, i.e, the marginal cost of preventive measures is equal to the marginal saving of social costs. The cost recovery strategy should be related to the distribution of marginal saving of social costs, as that would be the optimal situation under the willingness to pay approach.

The social costs of crashes in excess of these accident costs are caused by offenders. Ideally they should be borne by the offenders. Since the offences are not identifiable in advance, they can be controlled only through enforcement and punishment. The costs of enforcement and administration of punishment are the costs of preventive measures to reduce accidents. The optimal strategy would be to determine the enforcement and punishment levels in such a way that the marginal cost of enforcement including the administration costs of punishment is equal to the saving in social cost of crashes.

Should the enforcement cost be borne by only the offenders or by all road users? As the level of enforcement increases, the number of offences reduces. There can be a situation where the number of offenders apprehended is lower at high level of enforcement than at a lower level. The enforcement level is high in order to provide safe road transportation to all users. The net cost of enforcement (enforcement cost - fine revenue) should, therefore, be shared by all road users. In fact, it should not be confined to vehicle users only. A reduction in drink driving reduces the risks of injury and death to pedestrians and cyclists as well. How much should be shared by each user should depend on the marginal benefit of safety improvement enjoyed by the road user. This is based on the consideration that the marginal benefit of enforcement is measured by the amount society is willing to pay for reducing the risk of accidents.

5. CONCLUDING REMARKS

The main points discussed in the paper are:

1. The accident/crash risk can be divided into two components: the accident risk of driving - an inherent property of the road transport system and the additional risk caused by traffic offences.

2. The expected cost of accident on a trip by a traffic offender does not differ from that by a law abider.

3. The social cost of additional risk imposed by traffic offenders should be paid by the traffic offenders, in some form or the other. However, there are limitations caused by the financial ability of the offender, fatal or serious disability consequence to the offender and the society's responsibility to the welfare of the dependents of the offender.

4. The net cost of enforcement should be shared by all road users and other beneficiaries as prices paid for safety resulting from the enforcement and other preventive measures.

This paper is an attempt towards developing a framework for internalisation of safety externalities. The framework is far from complete. This needs substantial further research. Two fundamental areas would be to determine the optimal package of enforcement and punishment levels and the strategy for allocating the costs of preventive measures. Once these are established, the social cost of accidents under the optimal system becomes an inherent property of the system. How this social cost should be shared amongst the members of society is another complex issue to be dealt with.

6. NOTE

The views expressed in the paper are my personal views. These are not necessarily shared by the Land Transport Safety Authority.

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