Risk Homeostasis Theory in Traffic Safety

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1. Introduction

The traffic safety depends on the three elements: driver, vehicle and road. The driver is the least perfect and least predictable element in the traffic safety system. A fundamental premise of government policies is that it is possible to reduce the number of crashes and severity of accidents by improving the design of the road and use of safety devices, by educating the drivers and using enforcement. Wilde's theory of Risk Homeostasis proves that the premise is not entirely correct.

Engineering can provide an improved opportunity to be safe, education can enhance the performance skills, and enforcement of rules against specific unsafe acts may be able to discourage people from engaging in these particular acts, but none of these interventions necessarily increases the desire to be safe. If, however, safety is actually determined more by the motivation to be safe than by the physical opportunity that is offered or by the level of skill, the introduction of accident countermeasures of the engineering, education and enforcement varieties would not necessarily reduce the accident rate per head of population.

What may occur instead is behavioral adaptation, that is, a change in behavior that offsets the potential safety benefits, as has been discussed in a report by the OECD (1990). The greater opportunity for safety and the increased level of skill may not be utilized for greater safety, but instead, for more advanced performance: "Behavioral adaptations of road users which may occur following the introduction of safety measures in the transport system are of particular concern to road authorities, regulatory bodies and motor vehicle manufacturers particularly in cases where such adaptations may decrease the expected safety benefit" (OECD, 1990, p. 5).

The OECD report cited numerous examples of this phenomenon. Taxicabs in Germany equipped with anti-lock brake systems were not involved in fewer accidents than taxis without these brakes. Increases in lane width of two-lane highways in New South Wales in Australia have been found to be associated with higher driving speeds; for every 30 cm of additional lane width speed increased by 3.2 km/h. This was found for passenger cars, while truck speed increased by about 2 km/h for every 30 cm in lane width. An American study dealing with the effects of lane-width reduction found that drivers familiar with the road reduced their speed by 4.6 km/h and those unfamiliar with the road - by 6.7 km/h. In Ontario, it was found that speeds decreased by about 1.7 km/h for each 30 cm of reduction in lane width. Roads with paved shoulders as compared to unpaved shoulders in Texas were found to be associated with speeds at least 10 per cent higher. Drivers have generally been found to move at a higher speed when driving at night on roads with clearly painted edge markings.

The statement that the strength of the desire to be safe is the dominant factor in accident avoidance in the face of every-day physical injury risks on the road is one of the main contentions of Risk Homeostasis Theory.

2. Risk Homeostasis Theory

Risk homeostasis theory maintains that, in any activity, people accept a certain level of subjectively estimated risk to their health, safety, and other things their value, in exchange for the benefits they hope to receive from that activity (transportation, eating, recreation, drug use etc.).

In an ongoing activity, people continuously check the amount of risk they are exposed to. They compare this with the amount of risk they are willing to accept, and try to reduce the difference between the two to zero. Thus, if the level of subjectively experienced risk is lower than is acceptable, people tend to engage in actions that increase their exposure to risk. If, however, the level of subjectively experienced risk is higher than is acceptable, they make an attempt to exercise greater caution.

Consequently, they will choose their next action so that its subjectively expected amount of risk matches the level of accepted risk. During the next action perceived and accepted risks are again compared and the subsequent action is chosen in order to minimize the difference, and so on.

Each particular adjustment action carries an objective probability of risk of accident. Thus, the sum of total all adjustment actions across all members of the population over an extended period of time (one or several years) determines the temporal rate of accidents in the population.

These rates, as well as more direct and frequent personal experiences of danger, in turn influence the amount of risk people expect to be associated with various activities, and with particular actions in these activities, over the next period of time. They will decide on their future actions accordingly, and these actions will produce the subsequent rate of human-made mishaps. Thus, a ‘closed loop’ is formed between past and present, and between the present and the future. And, in the long run, the human-made mishap rate essentially depends on the amount of risk people are willing to accept.

This theory could be a possible explanation for the fact that the construction of modern multi-lane highways has contributed to a reduction in the number of road death per unit of distance driven, while the number of traffic deaths per head of population remained the same or even increased.

There is a growing body of evidence that points to the surprising conclusion that most coercive measures intended to increase safety either have no effect or an opposite effect. For example, we all know that drivers who wear seatbelts, on average, more likely to survive a crash than those who don’t. So we might be inclined to expect that laws compelling drivers to buckle up, and that increase in seat belt wearing rate, will reduce a nation’s traffic fatality rate per head of population. Thus, when the government mandates the use of automobile seat belts, fatality rates do not decrease as expected. This counter-intuitive result is consistent across a broad range of governmental attempts to protect people from themselves.

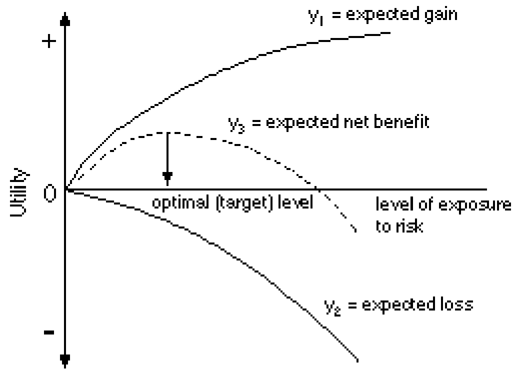
Gerald J.S.Wilde gives following argument: “A river empties into the sea through a delta. The delta has three channels, all of equal size. Therefore, damming two of the channels will reduce the flow of water to the sea by two-thirds.” In all likelihood, nobody would accept this argument. One cannot stem the flow as long as there remain alternative routes to the destination. One cannot reduce mortality due to accidents unless all opportunity for premature death were eliminated by law or made impossible through technological intervention.

The theory of risk homeostasis predicts that people become accustomed to some acceptable level of risk, and that when they are required to reduce a risk they are exposed to, they will increase other risks until they have re-established the level of risk they have become accustomed to.

If drivers are required to wear a seat belt, the evidence suggests that they drive faster, pass other cars more dangerously, put on make up and so on, so as to maintain the level of risk they are comfortable with.

Essentially all behavior may be viewed as risk-taking behavior. ‘Zero risk’ is not a meaningful goal, as it can only exist in the absence of behavior. According to risk homeostasis theory, an individual should attempt to optimize the exposure to risk in an activity, where ‘optimal’ means the degree of risk at which the aggregate needs of that individual are likely to become best fulfilled, instead of aiming at the elimination of risk. (Wilde, 2000) Figure 1 explains why we should look for optimal level of risk that is grater than zero.

Figure 1: Optimal level of accident risk.



People choose an amount and manner of mobility such that the associated level of subjective risk corresponds with the point at which the expected net benefit is maximal. Note that the curve Y_3 has been drawn so that each Y_3 value equals the corresponding value Y_1 minus the corresponding absolute value Y_2 (Wilde, 1988 and 1994).

Increasing driving speed and/or the amount of driving (miles driven) corresponds to moving fom left to right along the horizontal axis of exposure to accident risk. With increased exposure, both expected gains and expected losses increase. Greater speed means shorter travel time towards the destination as well as more thrill and excitement. A greater distance driven means more mobility. Greater speed, however, also means more vehicle operating costs (e.g. higher gasoline consumption), a chance of a traffic ticket and more severe consequences if an accident were to happen.

For each combination of speed and distance of driving, the expected net benefit equals the expected gain minus the expected loss. In Figure 1, the curves describing expected gain and expected loss have been drawn such that the expected net benefit curve rises from left to right, then reaches a top which is followed by a decline. At zero exposure to risk, there is no mobility and the net benefit of mobility is nil. When speed is extremely high, the expected loss is greater than the expected gain and the expected net benefit falls below zero.

The extremes are thus to be avoided: while it is obvious that people should not maximize the danger of accident, neither should they opt for the other extreme of minimizing accident risk. Gerald J.S.Wilde suggests that people should attempt to maximize the expected net benefit from road travel and choose a speed and other actions accordingly. They should, therefore, try to select a level of exposure to accident risk that is greater than zero and that promises maximal net benefit from the behaviors chosen, that is, the target level of risk. Since zero risk is obviously not a meaningful goal, people target their risk level above zero.

3. Traffic accident rate per capita as the measure of safety

Risk Homeostasis has plausibility. Unlike safety engineers, who dedicate their lives to reducing accidents, people don't usually want to keep their accident rate at the absolute minimums. Indeed, many people voluntary engage a risk behavior such as car racing, mountain climbing, gambling and so on.

According to Gerald J.S.Wilde, safety improvement per unit distance of mobility has following effect:

- Increase in drivers' moving speed,
- Increase in mobility per head of population,
- No effect upon the annual traffic accident rate per capita.

The annual traffic accident rate per capita depends upon the level of accident risk people are willing to accept in return for the benefits they expect from their amount of mobility and the behaviors they display in traffic. Therefore, in order to be effective in reducing the accident rate per head of population, accident countermeasures must effectively reduce the level of traffic accident risk people are willing to accept.

It can be argued that there are predictable relationships from year to year between the following three variables:

1. the accident rate per mile driven (acc/mi),
2. the vehicle milage per head of population (mi/cap),
3. the accident rate per head of population (acc/cap).

The simplest relationship is:

(acc/mi) x (mi/cap) = acc/cap

More interesting seems to be relationship between accidents per mile driven and miles per capita. After some safety improvements have been made, an inverse relationship between acc/mi and mi/cap has been expected. In other words, if there is an increase in the total distance driven per head of population the accident rate per unit distance should go down.

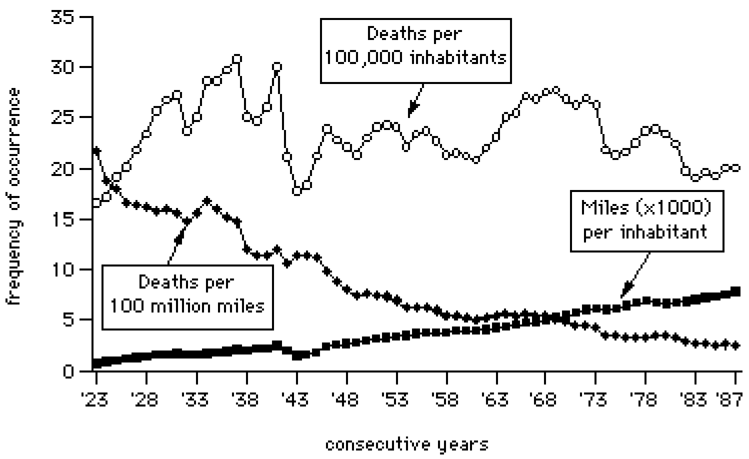
According to risk homeostasis theory this phenomena can be explained as follows. Accident countermeasures that are successful in lowering number of accidents per mile are those that allow drivers to proceed at a greater speed without altering their risk of accident per hour of exposure to traffic. Safety can be enhanced by offering drivers protection from the consequences of risky behavior, and that can be done by making the environment more forgiving.

There is another category of accident countermeasures, the rational of which appears to be exactly the opposite. By using these countermeasures, safety can be enhanced by making the consequence of risky behavior more severe.

Neither of categories, however, can be expected to alter the level of traffic accident risk accepted by the people. Examples of measures that aim at protecting drivers from the consequences of risky behavior include the manufacturing of more crashworthy cars, the installation of seatbelts, anti-lock breaks (ABS) and airbags, the widening of roads and the construction of divided highways. When drivers see no reason to alter their level of accepted risk thanks to these interventions, they will respond to the perceives potential safety benefits of such interventions by traveling at higher speeds and/or by driving more miles per period of time.

Available statistical data were inspected on the relationship between a drop in the accident rate per unit of distance and an increase in the distance driven per head of population. (see Figure 2).

Figure 2: Traffic death rate per distance traveled, traffic death rate per capita, and the distance traveled per capita in the U.S., 1923 – 1987. (Wilde, 1994)



The rate expressed as fatalities per 100 million miles driven shows more or less regular decline from year 1923 to 1987. The total mileage per head of population shows exactly the opposite – more or less regular increase.

The product of the data points on these two curves equals the number of death per 100, 000 inhabitants. This rate doesn't have clear trend over the period of time. There can be observed ups and downs around the average of about 23 deaths per 100,000 inhabitants, but over more than 60 years no consistent trend can be detected.

4. Support of Risk Homeostasis Theory

The earliest manifestation of risk homeostasis was among drivers. The debate began with the publication of the classic paper by Sam Peltzman "The Effects of Automobile Safety Regulation". In it he states: "The main conclusion is that safety regulation has had no effect on the highway death toll". He analyzed fatality data from 1947 to 1972. In 1968, Congress mandated safety equipment such as seat belts, energy absorbing steering columns, dual breaking systems, penetration resistant windshields and others. The safety community predicted roughly 20 percent reduction in fatality rates as a result of the huge expense of installing this equipment in millions of cars. Peltzman found none.

In 1973 the U.S. government reduced the speed limit to 55 mph and then allowed states to raise it again in 1987. Since some states did so, and other did not, researchers found it as good example to compare results.

It was expected that highway fatalities would go up by 4400 to 6000 per year. (Filley, 1999). Forty states increased speed limits, but rather than an increase in highway fatalities, they achieved a slight reduction in state-wide highway fatalities of 3.4 percent, as compared to the states that did not increase their speed limits. When people were forced to drive more "safely", they consumed their safety in aggressive lane-changing, daydreaming or some other behavior in order to re-establish their prior risk level. When allowed to drive faster, drivers seem to have realized the additional risk and adjusted their driving behavior accordingly.

Traffic lights are widely used to improve traffic safety at intersections. According to Gerald S.Wilde, numerous studies on the effect of traffic lights on accidents have compared the numbers of accidents at intersections before and after installation. The effect is that fewer right-angle collisions happen, but more rear-end accidents, as well as left-turn and side-swipe collisions occur, and thus the total frequency remains roughly the same. Traffic lights help more cars get through the intersection and this partly explains why accident rates do not change. The likelihood of an individual vehicle getting into an accident is less, but the total number of accidents at the intersection stays nearly constant.

5. Arguments against risk homeostasis theory

Many opponents of the theory try to object that most data supporting risk homeostasis use fatality rates rather than accident rates. Supporters explains that this is because statistics collected for fatal accidents are more accurate then those for non-fatal accidents. Many non-fatal accidents may never been reported and so never brought to the attention of the statistic gatherers.

People who try to refute the risk homeostasis as an argument use the death rate per mile driven that has been reduced by various mandatory safety measures. Everything depends on how fatality rates are measured. At first glance, the risk of death per mile driven may seem nearly identical to the risk of death per hour driven, but they are different. Looking at the example of traffic lights above, it is clear that when a traffic light is installed, more cars will get through the intersection per hour. If the observer would count number of crashes happened each hour, the number probably would stay about the same. If the observer would also count the number of cars, and then combine these data to get the accident rate per mile driven, there might or might not be a decrease in accident rate. If people really consume their extra safety with faster driving, then the accident rate per mile driven may change while the accident rate per hour stays the same.

Most researchers agree that people adjust their behavior to compensate for the risk they perceive. The debatable question is how much do they compensate. The theory of risk homeostasis predicts that people will consume roughly all the enhanced safety imposed upon them in other desirable risky activities (e.g. more exciting driving to fight boredom, eating or talking on the phone while driving and so on). Those who dispute risk homeostasis argue that although people compensate for the additional safety, they do not compensate completely therefore leaving a net gain in safety. D.Filley offers three possibilities that might clear this argument:

- If some net gain in safety turns up in statistics, then opponents of risk homeostasis are correct.
- If little or no change appears, then risk homeostasis theory is valid.
- If there is a net loss in safety, then risk homeostasis is not only valid but that means that people overestimate the additional safety forced upon them and behave even more recklessly or carelessly than necessary to keep their risk level constant.

People may think that the safety measures have made them so safe that they take more risks than would compensate for the measures imposed on them in the name of safety.

6. Conclusion

Of all countermeasures that affect people's motivation towards safety, those that reward people for accident-free performance seem to be the most promising. To maintain that safety is its own reward is to ignore the fact that people knowingly engage in risky behaviours in anticipation of benefits expected from those behaviours.

Of all possible incentive schemes that reward people for accident-free performance, some promise to be more effective than others because they contain the elements that appear to enhance motivation towards safety.

Different safety policies may have different influence on drivers' behavior. They can be grouped as following:

- The first group aims to reduce the severity of the consequences of risky behavior by the installation of seatbelts, airbags, crash barriers, wide roads and so on.
- The second group increases the severity of the consequences of imprudent behavior (e.g. seatbelts, narrow street passages, pavement undulation etc.)

Apart from noting that these two policies seem logically contradictory, it has been argued above that neither policy is likely to have en effect on the fatal accident rate per head of population, although they affect the accident rate per mile driven. The elements belonging to the first group causes the accident rate per mile to diminish, while the safety policy belonging to the second group can be expected to increase the accident rate per mile driven.

As regards the safety policies that make the consequences of risky behavior more severe, one problem in the evaluation of traffic safety measures is located in possible shift in traffic volume from the thread road sections to other roadways. Accident migration would thus be a result.

Areas for improvement:

- To provide roads that help drivers make correct decisions,
- To provide roads that forgive (drivers will stray from the ideal driving path)
- Need to expand professional thinking of transportation engineers into an integrated traffic safety system model where engineering accommodate the humanity of drivers. (Sany R.Zein, 1998)

People routinely behave more cautiously when they consider themselves at risk. People drive more slowly in the rain or snow. In the terminology of safety engineering that is known as risk compensation. (Filley, 1999)

The theory of risk homeostasis proposes that a nation's temporal loss due to accidents is the output of a closed-loop regulating process in which the accepted level of risk operates as the unique controlling variable.

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