RISK AND RISK HOMEOSTASIS

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Abstract

We consider the diversity in the definition and application of risk, objective and subjective risk in particular with reference to rare event are discussed Wild's theory of risk homeostasis is expanded in the context of road accidents.

1. Introduction

The term 'risk' is often used to mean simply "probability" but with a judgement of the event whose probability is being assessed. In this sense the verbal relationship between probability and risk is somewhat like the distinction between "and" and "but" logically equivalent but semantically district. It might be possible to speak of the risk of getting heads in the toss of coin, and this would be understood to mean the probability of that event, with the customary scaling on the unit interval. However, unless the event "heads" carried with it some unfortunate consequence, the use of the wood "risk" in such a context would appear somehow inappropriate.

Hauer (1982) defines "risk is the probability (chance) of accident occurrence" and other authors although not starting the identity so explicitly seem to agree with the idea. It is noteworthy that if the definition of risk were this simple, there would no need for the term "risk" at all.

Taha (1982) explains risk in term of business context. In risky situations the profit c_j will no longer be a fixed value, rather, it is a random variable whose exact numerical value is unknown but can be responded in terms of probability density function, $f(c_j)$. Thus it does not make sense to take about c_j without associating some probability statement with it. The profit contribution of the variable $c_j x_j$ is also a random variable whose exact value for a given value of x_j is unknown.

Risk appears to be reserved for those probabilities which must be estimated empirically. In this sense, we can speak of the risk of an earthquake, a telephone system overload. Also with definition the scaling to the until interval is still necessary, if we are to equate risk with probability.

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Risk is conceived as being a time dependent quantity, and so should be formalized as a function r (t) of a continous time parameter, with values in the until interval (0, 1). A parallel for such a quantity in applied mathematics; for example the time varying parameter representing the probability of a random occurrence, such as demand for service.

The probability of an interval exceeding t between two consecutive arrivals is the same as the probability of no arrival is same as zero. The probability of no arrival in the interval t immediately following the first arrival. i.e. $e^{-\lambda t}$

Thus by Poisson process

$$P(A = r) = \frac{(\lambda t)^r e^{-t\lambda\Delta}}{r!}$$

$$P(A = 0) = e^{-t\lambda\Delta}$$

$$r = 0, 1, 2, \ldots\ldots 00$$

$$P \text{ (no unit arrival at interval t)} = e^{-\lambda t}$$

$$P \text{ (no unit arrival at interval } \Delta t) = e^{-\lambda\Delta t}$$

$$P \text{ (at least one unit arrival at interval t)} = 1 - e^{-\lambda\Delta t}$$

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$$= \lim_{\Delta t \to \infty} (1 - e)^{-\lambda\Delta t}$$

$$= \lambda e^{-\lambda\Delta t}$$

Risk may be present in any activity. It is usually be slight. If we were to contact the riskiest traffic situation imaginable, perhaps an angry drunken dull - witted young male, the risk of collision would still be evaluated as beginning with several places of zeros. Only in abnormal situation like warfare do risk appear to be truly significant. A probability equal to zero does not imply an even which is impossible. It is acceptable to speak of an accident occurring at zero risk. The choice of a point at random on a line segment is an example of the proceed occurrence of an event of probability zero.

If we confine risk to the unit interval, we are prohibiting certain kinds of additivity. If the risk today is P and risk tomorrow is q we cannot claim that the risk over these two days is p + q: If we adopted such formulation it would be easy to find risks greater then one. A probability represents the probability of some "event" in the case of risk, the event would be an accident, or more specifically, an accident classified by time place type etc. Thus, if E represents a broken arm, F a broken leg, with corresponding risks p and q the probability of a broken limb would be not p + q but rather p + q minus the risk of the both a broken arm and broken leg. This restriction on additivity is a necessary consequence of the definition of risk as probability.

2. Object Risk Vs Subject Risk

However defined, it is clear that risk is a quantity to be estimated rather then deduced. By estimation, we included conventional statistical estimation, informed opinion based perhaps on precedent, as well as technical studies such as engineering analysis of components. In such a situation it is clear that estimates may vary, depending on the amount of information available and the strength of the estimation procedure. The road user's ability to evaluate risk is that he may be basing individual conclusions largely on the particular situations which he confronts from moment to moment, rather than on large scale averages available to the expert. For example few would doubt that running red light is in general considerably riskier than not doing so, is minimal or even zero, so that a rational being would be deterred by fear or arrest, social disapproval or some extraneous consideration. There are many situations in driving on automobile where perceived behaviour implies inaccurate calculation of risk. The number of accidents occurring also seems to furnish proof of drivers inability always to calculate risk, or to respond appropriately to the collection, even though accidents may occur at zero risk. In this circumstances driver's failure to take suitable precuation such as wearing a seat belt, remaining sober and riving slowly can be understood as logical even if not desirable from the point of view of society.

The overall picture of risk, therefore, consists, for a particular driver on a particular journey, of two time-dependent curves one "objective" and one "subjective". The relationship between these curves may vary with time and also with the driver involved. The doctrine of "perceived risk" (i.e. subjective risk) as now employed by traffic safety agencies applies to situations whose the driver's perception of risk is intended to be deliberately misled. The classic case is propaganda programs designed to make road users believe that the risk of arrest, of injury, or even of death is greater than expert calculations indicate to be the truth. Such attempts to separate belief from objective evidence are seldom successful except in the short run.

3. Risk Compensation

Scientific studies show that many drivers respond in some manner to changes in objective risk, to compensate for greater risk, or for lesser risk. A snowstorm will clearly produce slower traffic, conversely, melting snow and drying roads will be accompanied by higher traveling speeds. The concept of a compensatory loop appears in the literature as early as 1938 ***(Shah, 1994; Gibson and Cooks, 1938) Smeed (1949)*** also mentions a

> ***"body of opinion that hold that the provision of better roads for example, the increase in sight lines merely enables the motorist to drive faster, and the result is the same number of accident as previously".***

The first formed application of the risk compensation principle in the literature was Taylor's risk-speed compensation model ***(Tayler, 1964).*** Its basic tenet is that the larger the perceived risk is the lower a driver chosen speed will be. In short the product of perceived risk and speed is constant. The accepted level of risk is individual determined, partly on the interval factors such as age and meuroticism ***(Michon, 1985).***

Crownie and Calderwood (1966) formulated a "compensation principle" by arguing that accidents are the products of a simple closed loop model of the accident process. According to that process the favourable effects of a safety measure will be counter-balanced when the "warning" feedback is eliminated from the system.

4. Risk Homeostasis

Wild's theory of risk homeostasis is an principle that driver's attempt to establish a balance between what happens on the road and their level of acceptable subjective risk ***(Wilde, 1978, 1982; wilde and Murdoch, 1982).*** Essentially, wilde expended Taylor's compensatory model into a general theory of behaviour under uncertainty.

Wilde's risk's homeostasis theory (1978, 1982, 1985, 1986) proposes that an underlying feedback control system somewhat analogous to a thermostat operates to keep user risk at an essentially constant level. Basically this theory suggest that the overage collective risk is hold at a constant rate per unit of time and that it is independent of external changes, in much the same why that the thermal homeostatic system in warm blooded animals such as man keeps the body temperature essentially constant, independent of even large changes in ambient temperature.

5. Probability of Severity

We consider a population of traffic minded pedestrians with a probability density function of crashes $f_u(S)$. That is, given that those pedestrian who is not traffic minded is in a crash, the probability that is has severity s in $f_u(S)$. We consider s to be no more then some physical measure, or function of physical measure, with the probability that as s increases, the probability of a fatality increase from essentially zero at very low severities to essentially unity at very high severities.

Let us further assume that when a crash of severity s occurs, the probability that traffic minded pedestrian is killed is given by $q_{D}.u$ (s). Then the number of pedestrians who are not traffic minded killed is given by

$$N_u = N^1 \int_0^{\infty} q_{D}.u(s)/u(s)ds,$$

Where N^{-1} is the number of crashes per years by the pedestrians who are not traffic minded.

The precise meaning of traffic mindedness used here is based on asking how many of the pedestrians in the above population would have been killed if, instead of all pedestrians who are not traffic minded, they had all been traffic minded, other pre-crash factors remaining identical. Let us assume that the probability that a traffic minded pedestrian is killed when involved in a crash of severity s is q_{Db} (s) then the number of formally pedestrians who are not traffic minded have been killed had they were traffic minded is given by

$$N_b = N^1 \int_0^{\infty} q_{D\cdot b}(s)/u(s)ds,$$

Let us define the ratio

$$R_{true} = \frac{\int_0^{\infty} q_{D.b}(s)/u(s)ds}{\int_0^{\infty} q_{D.u}(s)/u(s)ds}$$

The only difference in the denominator and numerator is the probability of fatality as a function of severity, the distribution of crash severities is the same in denominator and numerator. Hence, R_{true} measures the ratio of new to old fatalities, assuming that a formerly those pedestrians, who were not traffic minded became a traffic minded pedestrians, with nothing else changing. To evaluate effectiveness of traffic education we have

$$\text{Effectiveness} = 1 - R_{true} \times 100$$

The equation above constitutes some degree of simplification in that severity is intrinsically a vector rather then scalar quantity. This is because the probability of fatality depends on pedestrian age, behaviour, mental state, education.

Let us consider that there were N_t total crashes in which (the pedestrians who were traffic minded) both type of pedestrians were involved (traffic minded and not traffic minded). Then the total number of pedestrians killed in these crashes is given by

$$d = N^1 \int q_D(s) f_1(s) ds$$

and the total number of pedestrians killed is given by

$$e = N^1 \int_0^{\infty} q_p(s) f_1(s) ds$$

The fatality ratio of traffic minded and not traffic minded pedestrians is given by

$$r_1 = \frac{\int_0^{\infty} q_D(s) f_1(s) ds}{\int_0^{\infty} q_p(s) f_1(s) ds}$$

Consider another group of pedestrians (including both traffic and not traffic minded) the fatality ratio would be

$$r_2 = \frac{m}{n} = \frac{\int_0^{\infty} q_D(s) f_2(s) ds}{\int_0^{\infty} q_p(s) f_2(s) ds}$$

Let us define

$$R = \frac{r_1}{r_2} = \frac{nd}{me}$$

Or

$$R = \frac{\int_0^{\infty} q_D(s) f_1(s)\, ds \int_0^{\infty} q_P(s) f_2(s)\, ds}{\int_0^{\infty} q_P(s) f_1(s)\, ds \int_0^{\infty} q_D(s) f_2(s)\, ds}$$

Relating the fatality counts to the true effectiveness

$$R_{true} = \beta R$$

The factor β is a biasing or correcting, factor relating our estimate of effectiveness, R_1 to its true value; β is given explicitly by

$$\beta = \frac{\int_0^{\infty} q_{D\cdot}(s) f_2(s)\, ds}{\int_0^{\infty} q_{P\cdot}(s) f_1(s)\, ds} \cdot \frac{\int_0^{\infty} q_{P\cdot}(s) f_1(s)\, ds}{\int_0^{\infty} q_{D\cdot}(s) f_2(s)\, ds}$$

Thus we conclude that the ratio of fatality counts, nd/me estimates the true effectiveness of traffic safety education in preventing pedestrian fatalities provided β = 1. If we attempt to measure the effectiveness of traffic safety education by comparing traffic minded pedestrian fatalities per crash to the fatalities of those pedestrian who are not traffic minded, the lower crash sererities for traffic minded pedestrians compared to those pedestrians who are not traffic minded directly biases effectiveness estimates upwards.

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