On the Conservatism Implicated in the Defaults for Regulatory Railway Risk Analysis

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ABSTRACT

How to choose defaults for railway risk-informed regulations depends on the conservatism implicated in the regulatory defaults. Without a universal agreement on the approaches for dealing with the conservatism of the defaults, however, the desirability of conservatism in the regulatory risk analyses has long been controversial. An opponent views it as needlessly costly and irrational, and a proponent as a form of protection against possible omissions or underestimations of risks. Moreover, the inherent ambiguity of a risk makes it difficult to set suitable defaults in terms of a risk. This paper focuses on the effects of the different levels of a conservatism implicated in regulatory defaults on the estimates of risk. Understanding of the effect of conservatism in the regulatory defaults can help decision makers evaluate the levels of a safety likely to result from their regulatory policies.

1. INTRODUCTION

Most individuals and agencies in the world have always endeavored to avoid undesirable risks, or at least to bring them under control. Despite these efforts, however, no attention has been paid to some risks as yet. Moreover, new risks that are highly difficult to manage continue to emerge from the use of high technologies, such as high-speed railway, chemicals, aircrafts, nuclear power, and so on. In seeking to control these risk issues, it is necessary to impose several types of regulations on those responsible for the risks, thus ensuring that they are the most effective ways to reduce risks, or to allocate limited resources to do this. Ideally, the optimal balance between a relevant measure of benefit and cost should be produced in this regulatory process.

Even though both regulators and regulated parties generally recognize the potential benefits of a risk-informed regulation, this approach makes slow progress to be adopted in practice. The barriers to implementing a risk-informed regulation are largely the same as the barriers to implementing quantitative safety goals, which are inherently attributable to the ambiguities of a risk (Griesmeyer and Okrent, 1980). In spite of such ambiguities, 'defaults' (also often called ‘requirements’, ‘acceptance criteria’, or ‘standards’ with the diversity of applications)[1] are frequently used as important elements of a formal risk analysis and decision-making for a risk-informed regulation. However, the expression of regulatory defaults in terms of a risk should be given attention, because they are fundamentally liable to a misinterpretation.

The question of whether or not regulatory defaults should be set conservatively has long been controversial (National Research Council, 1994). The opponent views it as needlessly costly and irrational, and the proponent as a form of protection against possible omissions or underestimation of risks. Currently, agencies differ widely in their approaches to regulatory defaults, and the implications of these differences are not well understood as yet. For example, in the EPA risk assessment guidance for the Superfund program (USEPA, 1991), the approved defaults for a variety of quantities are described as "90th-percentile," "reasonable upper-bound," and "reasonable worst case." In the nuclear power industry (Nuclear Regulatory Commission, 2002) and railway industry (Railway Safety, 2003), by contrast, defaults for their risk analyses have generally been set at or near the mean of the industry to determine the right priorities for the risks. It is because the adoption of conservative defaults can cause irrelevant priorities of the risk-critical components, so-called a shadow effect (Bier and Jang, 1999).

More importantly, regulators and regulated parties have systematically different goals or utility functions. In particular, regulators have a natural incentive (and in fact often a mandate) to seek large safety margins (*e.g.*, by ensuring that risks are estimated conservatively). However, the cost of complying with regulations may be a secondary consideration for regulators. Regulated parties also have an incentive (in fact, a direct financial incentive) to ensure the safety of businesses that they own and operate, but in their case this is balanced by a competing desire to minimize their costs. Given the changes in some industries (*e.g.*, the railway industry of increased competition), the urgency of a cost minimization is if anything likely to increase in the next few years. Therefore, once a regulated company has achieved a level of safety that is acceptable from a corporate point of view, it will generally have an incentive to ensure that the risks disclosed to regulators are not overestimated, in order to avoid additional burdensome regulation and the reduced operational flexibility that will be likely to result.

This paper focuses on the effects of different levels of a conservatism implicated in the regulatory defaults on the estimates of a risk. Note that we do not take any position on the merits of conservatism *per se*, but rather explore the effects of different levels of conservatism, and their implications. Understanding of the conservatism implicated in regulatory defaults in terms of a risk can help decision makers evaluate the levels of a safety likely to result from their regulatory policies.

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[1] In the paper, 'defaults' are defined as officially approved modeling assumptions and parameter values of many uncertain and/or subjective quantities to be often specified by regulators and considered acceptable for use in risk analyses as input to regulatory decisions.

2. NOTATIONS AND GENERAL FORMULATION

Fortunately, the effect of a conservatism implicated in the regulatory defaults is a topic that is amenable to fairly rigorous mathematical analysis, by using simple but plausible models of a regulated party behavior. In particular, let X be the (uncertain) estimate of a risk (or a risk-related parameter such as a component failure rate) which would result from a risk analysis performed using realistic parameter values and assumptions. Let us assume that the variability of X across the population of the regulated parties is described by the probability function, $f_X(x)$. Furthermore, let D be the default value chosen for the same quantity. For example, if a regulated party elects to use the default rather than a realistic analysis, the same value D would be used by any regulated party in the population, regardless of its value of X. Thus, it is reasonable to assume that the risk estimate disclosed to the regulators by a regulated party, Y, depends on the behaviors of the regulated parties as follows.

$$Y = h(X, D) \tag{1}$$

where h is the function to represent the behaviors of the regulated parties. Finally, the expectation of $T\ (= Y/X)$, $E[T]$, will be adopted as a simple measure to evaluate the effect of a conservatism implicated in a particular regulatory default (D) on the estimates of a risk.

3. THE EFFECT OF CONSERVATISM IN REGULATORY DEFAULTS

3.1 Maximum Gross Effect

First, Bier and Jang (1999) assumed that the regulated party has perfect knowledge about its value of X (*e.g.*, it has already done a realistic risk analysis and is deciding whether to disclose the results to regulators). So, they suggested the risk estimate disclosed to the regulators by a regulated party as follows.

$$Y = X \wedge D \tag{2}$$

where $X \wedge D$ represents the minimum of both quantities, $\{X, D\}$. In other words, it means that the regulated parties will disclose the realistic risk estimates when they are more favorable than the approved default, and will use the default value when that is more favorable. These simple assumptions will be relaxed in succeeding subsections. For convenience' sake, the expectation of T defined in Bier and Jang (1999) will be called the maximum gross effect (MGE) in the paper.

MGE can be obtained in a closed form for an arbitrary distribution of a regulated population as follows (Note that there is no analytic results in Bier and Jang (1999)).

$$MGE = \int_0^1 \frac{D}{t} \cdot f_X\left(\frac{D}{t}\right) dt + F_X(D) \tag{3}$$

where F_X is the cumulative distribution function (CDF) of X.

MGE value ranges over (0, 1), and means that the risk estimate disclosed by the regulated party will be on average $[1-MGE]\times 100\%$ lower than the real risk estimate. Also, note that this degree of underestimation is an upper bound on the effect which might be observed in the real world, since the behavior of a regulated party assumes a perfect gaming, *i.e.*, perfect choice of the minimum value to be disclosed with perfect knowledge about the value of X . The second column of Table 1 shows the results of MGE for some distributions, by using mean value defaults. Some results for particular distributions such as uniform and exponential distributions were calculated exactly by using equation (3), while others for less tractable distributions were based on a simulation.

Table 1 Underestimation of Risks Using Mean Value Defaults* (MGE, MPE)

Distribution	MGE	MPE
Exponential	0.85** (0.84 ± 0.03)	0.59 ± 0.04
Weibull (shape parameter 2)	0.86 ± 0.02	0.72 ± 0.03
Weibull (shape parameter 3)	0.88 ± 0.02	0.78 ± 0.02
Weibull (shape parameter 5)	0.92 ± 0.01	0.85 ± 0.01
Uniform (lower bound=0)	0.85** (0.84 ± 0.02)	0.69 ± 0.02
Lognormal (Median=0.001, Error factor=3)	0.87 ± 0.02	0.66 ± 0.04
Lognormal (Median=0.001, error factor=10)	0.88 ± 0.03	0.52 ± 0.06
Lognormal (Median=0.001, error factor=30)	0.91 ± 0.03	0.41 ± 0.08
Lognormal (Median=0.001, error factor=100)	0.94 ± 0.03	0.40 ± 0.12

*Error bounds for simulation results are ±two standard errors. ** Analytic solutions

3.2 Maximum Pure Effect

MGE measures the gross average of the degree of underestimation due to defaults over the whole range of X . According to the circumstances, however, regulators may have an attribute to be more concerned about only the degree of a pure underestimation of the regulated risks (*i.e.*, only the case of $X > D$), because they have a natural tendency to seek large safety margins as mentioned previously. Moreover, if they have to set a new regulatory default, they may be concerned about the maximum pure underestimation of the risks disclosed to them by a regulated party in the future. Thus, the risk estimate disclosed to regulators by a regulated party will be simply defined as $Y = D$, given $X > D$. Considering the diverse concerns of a regulator on regulatory matter, we suggest another measure, so-called the maximum pure effect (MPE), as follows.

$$MPE = E(T|T<1) = E\left(\frac{D}{X}\middle| X > D\right) = \int_0^1 \frac{D}{t}\cdot f_X\left(\frac{D}{t}\right)dt \qquad (4)$$

Note that MPE is defined as a conditional expectation and corresponds to the first term in the right hand side of equation (3) which is related to MGE. In other words, it means the pure effect of an underestimation due to the default specified by the regulators.

MPE means that the risk estimate disclosed by the regulated party will be on average $[1-MPE]\times 100\%$ lower than the real risk estimate from the viewpoint of the regulators. The third column of Table 1 shows the results of MPE for some distributions, given the mean value defaults. All the results were based on a simulation. Figure 1 shows the difference between MPE and MGE for the lognormal distributions with different error factors in detail. It can be regarded as the inevitable gap between the regulator and regulated party, which can occur frequently in the process of a risk-informed decision making.

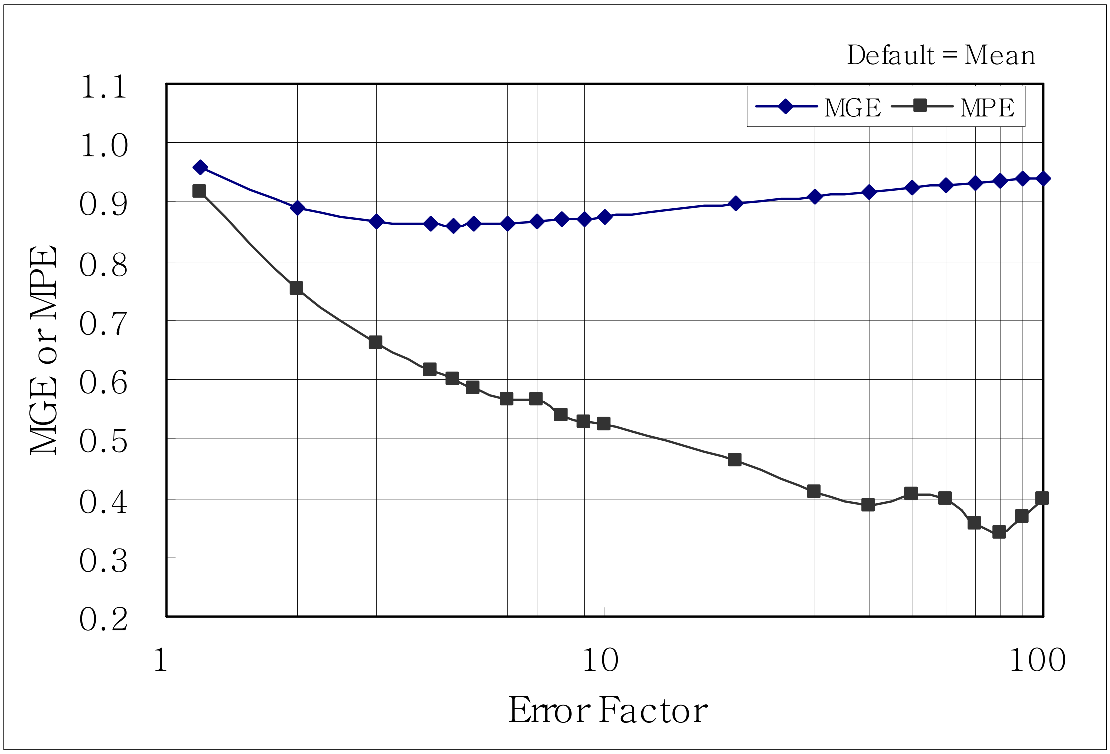

Figure 1 Comparison between MGE and MPE for Lognormal Distribution (Median=0.001)

4. CONCLUSIONS

The desirability of conservatism in regulatory risk analyses has long been controversial. It is seen by some as needlessly costly and irrational, and by others as a form of a protection against possible omissions or underestimation of risks. The intractability of this debate may arise in part because it views conservatism in isolation, rather than as one element of an overall regulatory system. Industry proponents of a risk-informed regulation must take seriously regulators' legitimate concerns about a bias, and develop mechanisms that can effectively constrain the potential consequences of such a bias. At the same time, regulators must be careful to ensure that their policies do not inadvertently create perverse incentives for the parties they regulate. Further research should focus on designing regulatory systems that simultaneously ensure adequate safety margins while encouraging the development and disclosure of realistic risk estimates.

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