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A RISK–BENEFIT–CONTROL PARADIGM FOR DECISION-MAKING[1]

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SUMMARY

This paper defines an abstract paradigm, and uses it to illuminate how risk should be considered in making decisions. The particular focus is on decisions by organizations with responsibility for controlling risks. This paradigm also is of use in providing insight into how the acceptability of risk varies in different situations.

The significance of risk to an individual depends on a number of factors, among these are:

1) Who gets the benefit?
2) Who gets the risk?
3) Who controls the risk?

By "control" is meant the power to decide whether to undergo the risk. To have true control one must understand the risk, hence control as used here means informed control. Below we define five archetype situations which vary in terms of who gets the risk, the benefit, and who has control. The paper will discuss the insights that can be gained by applying basic decision principles to the archetype situation defined in the paradigm.

Subject to the constraint that all of the risk, benefit, and control be assigned to one person, there are exactly five ways to distribute these attributes depending on how many 'persons' we allow. The risk, benefit, and control may all be assigned to one person (RBC); or each may be assigned to a separate individual for a total of three persons (R-B-C); or there may be just two persons, for which there are three possible combinations (RB-C, RC-B, and BC-R).

<u>Archetype Situation 1 Regulated Imposed Risk - 3 persons:</u>
In this archetype, person1 gets the benefit, person2 gets the risk, and person3 has control. This situation occurs when person1 is a regulated activity, person2 is an affected individual, and person3 is the regulator.

<u>Archetype Situation 2 Proxy Risk Tradeoff - 2 persons:</u>
In this situation, person1 gets both benefit and risk, but person2 has control. This situation arises in medicine, where the physician acts on behalf of patient in trading off risks and benefits.

[1] This paper was prepared by an employee of the U. S. Nuclear Regulatory Commission. It presents information that does not currently represent an agreed-upon staff position. NRC has neither approved nor disapproved its technical content.

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Archetype Situation 3 Rescue - 2 persons:

Person1 gets the benefit; person2 incurs risk but has control. This situation arises for rescuers who work in hazardous environments.

Archetype Situation 4 Unregulated Imposed Risk - 2 persons:

Person1 gets the risk; but person2 gets the benefit and has control. This is an inherently undesirable situation, as there is a conflict of interest for person2, who may thus not sufficiently limit person1's risk.

Archetype Situation 5 Voluntary Risk Tradeoff - 1 person:

Person1 gets the benefit and risk and has control. Here there is no conflict of interest, thus no need to rectify an inequity imposed on one person by another. The person simply is making a personal risk-benefit tradeoff decision, as in parachute jumping for recreation.

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INTRODUCTION

This paper defines an abstract paradigm involving risk, benefit, and control then uses it to provide insight into how quantitative assessments of risks and benefits should be used in decision-making. The main context envisioned for such decision-making here is in government regulation and management of health and safety, but the principles involved are quite general. The term risk is used here with a very general meaning of "adverse impacts". Generally the impacts of interest in this context are increases in risk or cost. By benefit is meant positive impacts, such as decreases in risk or cost. By control is meant the power to choose whether to incur a risk, or the power to limit or control its magnitude. Legitimate activities in society are conducted to produce benefits for the organizations conducting them. However, even a legitimate and beneficial activity may have adverse impacts (risks) as well. In fact, there may be multiple types of both positive and adverse impacts, which differ among different individuals or groups. While it is clear that it is desirable to increase benefits and reduce risks, the fact is that a given action may produce both effects, and may affect different persons differently. Hence, it is desirable to have precision decision-rules and principles in order to choose among alternative actions. To clarify this situation, an abstract paradigm will be presented in which five situations are defined with risk, benefit, and control being assigned to just one "person." These five situations will then be discussed in terms of basic decision-making principles applicable to regulation and management of public health and safety. The benefit of this approach is that the pure abstract situations clarify the rationale for regulatory and management actions that, in the real world, involve more complex situations where the risks and benefits of an action impact multiple persons in different ways.

THE RISK-BENEFIT-CONTROL PARADIGM

If one imposes the constraint that all risk, benefit, and control must be assigned to one, and only one, "person"; then there are exactly five ways that this can be done. If three persons are involved, then risk, benefit, and control can be assigned one to each of these persons. This situation can be symbolized as R-B-C. If only one person is involved; then risk, benefit, and control all are assigned that one person, symbolized RBC. If two persons are involved then there are three ways to assign risk, benefit, and control; namely as symbolized RB-C, R-BC, and B-CR. We refer to these five abstract situations here as archetypes. Each archetype is also given a title that evokes one of the major decision principles that it illustrates. The five archetypes are further defined in the following paragraphs.

<u>Archetype Situation 1 Regulated Imposed Risk - 3 persons:</u>

In this archetype, person1 is exposed to the risk from an activity conducted to benefit person2; while person3 controls the magnitude of the risk incurred. It is symbolized R-B-C, where the dashes separate the persons. This situation can occur when person2 is conducting an activity for his benefit, but there are adverse impacts or risks from it that are imposed on person1. Such imposed risks are referred to in economics as externalities or neighborhood effects. Person3 here could be a regulator or risk manager who has the authority to control whether and how much risk it is appropriate to allow.

<u>Archetype Situation 2 Proxy Risk Tradeoff - 2 persons:</u>

In this situation, person1 gets both benefit and risk, but person2 has control; symbolized RB-C. This situation arises in medicine, where the physician acts as a proxy decision-maker on behalf of a patient in trading off risks and benefits. For example, the physician may decide that a particular operation, which may have some risk of an adverse outcome, has benefits that exceed this risk.

<u>Archetype Situation 3 Rescue - 2 persons:</u>

Person1 gets the benefit; person2 incurs risk but has control; symbolized B-CR. This situation arises in rescues, where the rescuer voluntarily accepts some risk in order to provide a benefit (rescue) to the rescuee, person1.

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Archetype Situation 4 Unregulated Imposed Risk - 2 persons:

Person1 gets the risk; but person2 gets the benefit and has control; symbolized R-BC. This is an inherently undesirable situation, as there is a conflict of interest for person2, who thus may not sufficiently limit the risk to person1. The risk is thus imposed on person1 in that he has no control over whether it will occur. There is no third person to act as regulator.

Archetype Situation 5 Voluntary Risk Tradeoff - 1 person:

Person1 gets the benefit and risk and has control (RBC). . Here there is no conflict of interest, thus no need to rectify an inequity imposed on one person by another. The person simply is making a personal risk-benefit tradeoff decision, as in parachute jumping for recreation.

BASIC DECISION PRINCIPLES

In order to discuss how quantitative risk assessment can be used in making decisions concerning the above five archetype situations, it is necessary to establish a set of decision principles as a basic reference framework. The reference framework to be described here is one in which risk and other information is used directly by a decision-maker with the power to both make and implement the decision alternatives under consideration. This is unlike many real situations where decisions are made in an institutional or societal context where consent must be obtained from other persons. The principles referred to here come from the recommendations of the International Commission on Radiological Protection (ICRP) and from the U. S. Office of Management and Budget (OMB). The ICRP has recommended 3 basic principles of radiological protection [1] in the following statement.

> "A system of radiological protection should aim to do more good than harm, should call for protection arrangements that maximize the net benefit, and should aim to limit the inequity that may arise from a conflict of interest between individuals and society as a whole."

These are referred to succinctly as the principles of justification, optimization, and limits. Justification is the principle that society, or the government acting in its behalf, should not permit any activity whose net benefit to society is negative. That is, the risks and adverse effects should be outweighed by the benefits. The principle of optimization is that, given a situation where there are alternative choices, one should choose the one, which optimizes the net sum of benefits and risks. In the context of government and regulation, this means that governmental bodies should choose alternatives, which optimize benefits to the whole of the society. The principle of limits is that consideration of equity dictates that there be limits on the magnitude of risks imposed without their consent on any individual. These risks imposed on bystanders by beneficial economic activities in which they are not voluntary participants are known in economics as externalities. Regulation to limit externalities is often noted as one of the useful functions of government in a free enterprise system.

The principle of limiting adverse externalities applies to all types of adverse effects, but in this context we will focus on adverse health impacts. Adverse cost impacts can be recovered through actions under civil law. Death and other permanent health impacts cannot. Hence, the principle of limits when applied to health impacts implies a priori regulation to prevent or limit the impacts. Such health impacts may result from routine exposures to toxic or radiotoxic materials. Such routine exposures may be limited in magnitude by regulation, as in the U. S. Code of Federal Regulations 10 Part 20. The same principle applies to limitation of the risk from unintentional exposures (accidents). This idea of limiting accident risk has also been explicitly recommended in ICRP Publication 64 [2]. Routine exposures can be measured as they occur, but risk from rare potential accidents must be estimated by probabilistic risk assessment. It is important to note that the type of risk that is to be limited is risk to individuals. Hence, risk assessment to support the principle of limiting accident risk must calculate the risk to individuals, as in the annual probability of fatality, rather than some metric of collective risk across a population. In practice, the risk is often calculated for a single individual, the one who is at highest risk. If the risk to this individual is adequately limited, then it will be limited for all other individuals as well.

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In contrast, risks calculated for use in optimization are total collective risks summed across all affected persons. This is because the principle is to optimize the total impact of a proposed activity across the whole of society by evaluating a range of alternative ways of conducting that activity. This decision principle is recommended by the U. S. Office of Management and Budget to be applied to all proposed government regulatory actions that may have major impacts [3]. This type of optimization may be done quantitatively by evaluating all the cost and risk impacts of each of a number of alternative actions. The impacts are usually calculated relative to the alternative of no action, which thus has zero impact by definition. Alternatives, which increase risk or cost, are given negative impact values, while risk and cost decreases are positive. To tradeoff risk and costs, health impacts, both routine and accident, are conventionally converted to monetary units. The United Kingdom Health and Safety Executive [4] and the U. S. Nuclear Regulatory Commission [5] provide such conversion factors, and are of similar magnitude of about $3 million per statistical fatality averted. The usual decision criterion is that the alternative having the highest net impact is preferred. However, uncertainties in the evaluations must be taken into account in such decision-making, as many alternatives may be nearly equivalent relative to the uncertainty. Given such a quantitative net impact evaluation, the principle of justification can be reduced to the statement that activities whose total absolute net impact on society is negative should not be permitted.

The three decision principles discussed above are not the only considerations in risk-informed decision-making. A number of others are invoked in [5]. These include considerations that bear on the adequacy of attributes such as defense-in-depth, safety margins, and engineering standards that help manage uncertainties, hence limiting risk both quantitatively and qualitatively. Factors other than costs and health impacts, such as environmental protection and security threats, may also need to be considered.

RISK-INFORMED DECISION-MAKING AND THE RISK-BENEFIT-CONTROL PARADIGM

Each of the five archetype situations will now be discussed in order to clarify how risk factors into decision-making process.

Archetype Situation 1 Regulated Imposed Risk - 3 persons:

In this archetype, person1 is exposed to the risk from an activity conducted to benefit person2; while person3 controls the magnitude of the risk incurred. The principle of limits tells us that the risk to person1 from the activity conducted by person2 should be limited in its absolute magnitude. If person3, the one having control, is the regulator, we have the classic situation of regulation of externalities. The principle of optimization tells us that it is also proper to seek to reduce risks further by finding the alternative means of protection with the highest net benefit.

This archetype also illustrates why a risk may not be acceptable to a person even though it is properly limited and minimized. The reason is that the risk is imposed on person1 in the sense that person3 has control of this decision. In addition, the activity imposing this risk is not for the benefit of person1. Sandman [6] and others have pointed out that the acceptability of a risk depends on a number of factors related to control, knowledge, and benefit, not just on the magnitude of the risk, no matter how small.

Archetype Situation 2 Proxy Risk Tradeoff - 2 persons:

In this situation, person1 gets both benefit and risk, but person2 has control. This is a risk-benefit tradeoff. The decision principle here is analogous to optimization. That is, one seeks an alternative that provides the highest net benefit. If no alternative can be found that yields a net positive benefit, then the best alternative is no action. The principle of limits does not apply here because the risk is being incurred in order to gain the benefit. The usual reasons why control of such a tradeoff decision would inhere in a second person are either the inability of person1 to make the decision, or that only person2 has the knowledge and judgment to correctly evaluate both benefit and risk.

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In Archetype Situation 2, person1 may find the risk-benefit tradeoff acceptable, provided he has confidence in person2 to make this judgment correctly. The more desirable situation for person1, however, is to be able to make the risk-benefit tradeoff decision himself, but such a situation would be Archetype 5 below.

Archetype Situation 3 Rescue - 2 persons:

Person1 gets the benefit; person2 incurs risk but has control. This also is a risk-benefit tradeoff, but here different persons incur the risk and benefit. The benefit is a risk reduction for the rescuee, while there is increased risk to the rescuer. Essentially this is a societal tradeoff. That is, the principle of justification applies, the net benefit to society must be positive. That is the likelihood and consequences of rescue must outweigh the risks incurred by the rescuer in the process. This may be easily achievable if there are large numbers of persons to be rescued by a few rescuers. The principle of limits does not apply, if the rescuer truly is at liberty to choose whether to pursue the rescue.

However, in practice, the decision whether to engage in a rescue activity having risk may be made by higher officials, not the rescuer. In this case, we do not have Archetype Situation 3, because he rescuer does not have control. He is not at complete liberty to choose to accept the risk. Thus a realistic rescue case may be a blend of Archetypes 1 and 3. In such real cases, there should be limits on the absolute magnitude of the individual risk incurred by the rescuer. However, since this is a direct risk-risk tradeoff, the limits might be significantly higher than in the more common situation of Archetype 1 where the benefits are usually monetary.

Archetype Situation 4 Unregulated Imposed Risk - 2 persons:

Person1 gets the risk; but person2 gets the benefit and has control; symbolized R-BC. This is an inherently undesirable situation, as there is a conflict of interest for person2, who may thus not sufficiently limit the risk to person1. The risk is thus imposed on person1 without his consent, as there is no third person to act as regulator.

Archetype Situation 5 Voluntary Risk Tradeoff - 1 person:

Person1 gets the benefit and risk and has control. Here there is no conflict of interest between separate individuals; since there is only one. The principle of limits does not apply, as the person involved has control of the decision. The person simply is making a personal risk-benefit tradeoff decision. As previously mentioned, the concept of control as used here means informed control. The person making the decision must correctly understand the magnitude of the risks and benefits in order to evaluate the tradeoff. The activity meets the principle of justification if the net benefit is positive. However, the principle of optimization should also be applied. That is, the person should examine alternative ways of achieving the benefit while minimizing the risk. Some persons pursuing risky recreational activities may not be adequately applying this principle.

In real cases where individuals make their own risk-benefit tradeoffs, there are usually factors affecting risk that are actually controlled by other persons. For example, the equipment used may have been manufactured and tested by someone other than the user. Thus most real situations that appear to be a voluntary risk-benefit tradeoff have an element of Archetype Situation 1 in them. Thus we find a potential role for standards to limit and optimize the risk from these factors beyond the control of the user.

CONCLUSION

I have found, both in this paper and through professional experiences, that the five simple risk-benefit-control Archetype Situations defined here are useful in analyzing real situations to determine the correct application of the decision principles advocated by the ICRP [1 and 2] and the U. S. Office of Management and Budget [3].

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