Using and Understanding the Term RISK

Risk as the probability of an event occurring and its associated consequences

The word *risk* is commonly used, but because it can have many different meanings to different people and groups, it can become the source of misunderstandings and disagreements. In an effort to reduce the confusion, we prepared this document to identify one definition of *risk* for the symposium. The discussion below is not intended to redefine *risk* or advocate for a single approach, but to give all participants a common usage of the term for our discussions.

There are numerous formal and colloquial uses of *risk*. These different approaches and understandings are a product of individuals using the term within the context of their specific field or area of interest, and/or from a personal perspective. Discussions of *risk* often include both objective metrics and subjective reactions (i.e., emotional response: fear, outrage, desire, etc.).

Confusion over the use of the word *risk* can be compounded because the term may reflect many dimensions of review. It might be a single objective dimension, combine multiple-dimensions into one metric, or reflect a purely abstract emotional reaction. This reality can cause confusion in interdisciplinary discussions between scientists, engineers, policy makers, and lay audiences (all applying their own specific definition, dimension, or perception of *risk)*.

The word *risk* is often used to express other ideas, like hazard and impact. While these concepts are similar, they have different meanings and the use of the right term should be carefully chosen to talk about them. Hazard can be defined as an unavoidable danger or something causing unavoidable danger, and is a component of risk. During the symposium, we will try to avoid misuse of these terms and rely on using *risk* as defined in this paper.

Example uses of the term *RISK*

A biologist or chemist discussing risk might be talking about "potential harm" to an organism, or biological system (but not necessarily the mathematical probability of actual exposure, or the degree of exposure).

An investor's portfolio choices may be based on an emotional attachment or aversion to risk, and not an objective financial strategy (human emotions are often just as significant to understanding risk as are the technical, objective assessments of specific hazards or probability).

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A toxicologist reviewing risk might be focused only on dangerous exposure thresholds for specific organisms, or persistence of toxins within specific environments (this evaluation leaves out many other important elements of concern previously discussed).

A physicist calculating the risk of Earth's collision with an asteroid might be focused on pure "statistical probability" of impact (not the potential scope of the event, or specific harmful outcomes); and finally,

A government agency like Home Land Security seeks to use objective compound metrics when discussing risk related to the safety of hazardous material transport, so it combines complex statistical probability for material lost containment with potential hazards and impacts of actual exposure to people and the environment from those materials (however, they may not consider the very real subjective emotion felt by citizens within the transportation corridor, nor include specific data across multiple topographies, and both built and natural environments, etc.).

How *RISK* will be used during the symposium

For this symposium, we will talk about *risk* in two ways - qualitatively and quantitatively. The qualitative approach uses two key components and can be defined like this:

Risk as the probability of an event occurring and its associated consequences

This simplified definition is a good place to start when thinking about individual *risks*.

For example: What *risk* is there for human impacts due to a hazardous material spill from a train derailment?

To answer this question, one would look at the probability of a train derailment, probability of a related hazardous material spill, and the potential associated exposure (consequence) and harm anticipated. Decision makers can use this information to decide between choices, like the routing of trains or the movement of hazardous goods. While this definition might be easier to conceptualize, in practice it is difficult to use. A quantitative approach to *risk* can help when there are multiple factors in determining *risk*. Take for example the quantitative *risk* assessment below:

$$R = (M \times Z \times P) \times (N \times C)$$

- *R = direct human risk related to the spill of a hazardous material spill from a train derailment*
- *M = traffic flow*
- *Z = hazardous materials car derailment rate*
- *P = probability of substance release from a derailed hazmat car*
- *N = number of people within derailment zone*
- *C = rate of injury of a hazmat car release*

This equation is an example that scratches the surface of the quantitative potential of *risk* assessment. This type of quantitative approach may help decision makers understand specific situations that increase or decrease specific kinds of *risk* allowing for more nuanced choices. The specific quantitative approach taken will vary depending on the decision-making context, available data, and resources/funding for the assessment.

Another important factor in understanding and talking about *risk* is the concept of "conditional *risk*." The world is dynamic, with outcomes dependent on previous events. Conditional *risk* is a term used to help talk about the change in the *risk* of an event given that another event has already occurred. Conditional *risk* can work in a multitude of ways, increasing or decreasing the probability of an event happening and/or the impact of its associated consequences. Conditional *risk* is largely the forum of modelers and analysts, but it is important for our basic understanding to note that *risk* is not static, and can be conditioned upon other events occurring.

While we highlight a specific use of the term *risk* for this symposium, we understand that there are many other valid uses and definitions of the term. Attached to this document you will find multiple additional sources defining and discussing the nature of *risk* to help each of us better understand how we have developed our own use of the term, and also why it is important to be clear about definitions of *risk* within multidisciplinary discussions.

Additional definitions of RISK and relevant publications

Department of Homeland Security. *DHS Risk Lexicon*. (Department of Homeland Security, 2010) https://www.dhs.gov/dhs-risk-lexicon

- Produced by the Department of Homeland Security Risk Steering Committee to "make available a common, unambiguous set of official terms and definitions to ease and improve the communication of risk-related issues for DHS and its partners."
- *Risk*: potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences.

Terje Aven, Henning Boje, Tony Cox, Enrique Lopez Droguett, Michael Greenberg, Seth Guikema, Wolfgang Kroger, Ortwin Renn, Enrico Zio. *Risk Analysis Foundations.* (Society for Risk Analysis, 2015). http://www.sra.org/sites/default/files/pdf/FoundationsMay7-2015-sent-x.pdf

- This paper does not aim to provide agreed basic pillars for risk analysis as a field, rather it wants to serve as a stimulator of discussion about what these pillars can and should be.
- There are different qualitative definitions of *risk*:
    - The possibility of an unfortunate occurrence
    - The potential for realization of unwanted, negative consequences of an event
    - The exposure to a proposition of which one is uncertain
    - The consequences of the activity and associated uncertainties
    - The uncertainty about and severity of the consequences of an activity with respect to something that humans value
    - The occurrences of some specified consequences of the activity and associated uncertainties
    - The deviation from a reference value and associated uncertainties
- *Risk* can also be quantified using different metrics:
    - Combination of probability and magnitude/severity of consequences
    - Triplet scenario/probability of that scenario/consequence of that scenario
    - Expected number of fatalities in a specific period of time or the expected number of fatalities per unit of exposure time
    - Product of the probability of the hazard occurring and the probability that the relevant object is exposed given the hazard, and the expected damage given that the hazard occurs and the object is exposed to it
    - Possibility distribution for the damage

Oxford English Dictionary

- *Risk*: possibility of loss, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility

ISO/IEC *FDIS* 31000: Risk Management
http://www.praxiom.com/iso-31000-terms.htm#2.1_Risk

- International Organization for Standardization guide to help organizations increase the likelihood of achieving objectives, improve the identification of opportunities and threats and effectively allocate and use resources for risk treatment.
- *Risk*: effect of uncertainty on objectives

National Research Council. *Science and Decisions: Advancing Risk Assessment*. (The National Academies Press, 2009)
https://www.nap.edu/catalog/12209/science-and-decisions-advancing-risk-assessment

- This publication is a complement to the 1983 book "Risk Assessment in the Federal Government" and these are essential references for those working in the regulatory and public health fields.
- *Risk*: a hazard, a probability, a consequence, or a combination or probability and severity of consequence.

National Research Council. *Understanding Risk – Informing Decisions in a Democratic Society*. (The National Academies Press, 2009)
https://www.nap.edu/catalog/5138/understanding-risk-informing-decisions-in-a-democratic-society

- Draws conclusions about what society should expect from risk characterization and offers clear guidelines and principles for informing the wide variety of risk decisions that face our increasingly technological society.
- *Risk*: concept used to give meaning to things, forces, or circumstances that pose danger to people or to what they value. Descriptions of risk are typically stated in terms of the likelihood of harm or loss from a hazard and usually include: an identification of what is "at risk" and may be harmed or lost (e.g., health of human beings or an ecosystem, personal property, quality of life, ability to carry on an economic activity); the hazard that may occasion this loss; and a judgment about the likelihood that harm will occur.

Dagmar Schmidt Etkin. *Risk Assessment of Oil Spills to U.S. Inland Waterways*. (Environmental Research Consulting, 2006)
https://archive.epa.gov/emergencies/docs/oil/fss/fss06/web/pdf/etkin_2.pdf

- A risk assessment of nearly 52,000 oil spills that have occurred in US inland navigable waterways since 1980 was conducted incorporating the probability of oil spills being from particular source types, oil types.
- Spill *risk* = (probability spill) * (average spill volume) * (impacts spill)

U.S. Environmental Protection Agency. *Risk Assessment.*
https://www.epa.gov/risk

- The EPA uses risk assessment to characterize the nature and magnitude of health risks to humans and ecological receptors from chemical contaminants and other stressors that may be present in the environment.
- *Risk*: chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor.
- *Risk* depends on 3 factors:
    - How much of a chemical is present in an environmental medium?
    - How much contact a person or ecological receptor has with the contaminated environmental medium
    - The inherent toxicity of the chemical

Xiang Liu, M. Rapik Saat, Christopher P. L. Barkan. *Safety Effectiveness of Integrated Risk Reduction Strategies for the Transportation of Hazardous Materials by Rail*. (Transport Research Record, 2013)
http://railtec.illinois.edu/articles/Files/Journal%20Articles/2013/Liu-2013-TRB.pdf

- This study represents the first step in a systematic process of quantitative risk analysis of railroad freight transportation for local, regional, and system-wide safety improvement and is intended to assist decision makers in the development of an integrated cost-efficient risk reduction framework.

- *Risk*: R = Z * M * P * C, where
    - R = hazardous materials release risk (expected of number of people affected)
    - Z = hazardous materials car derailment rate per billion car-miles
    - M = traffic exposure (billion car-miles)
    - P = conditional probability of release of a derailed hazmat car
    - C = consequence of a hazmat car release (e.g., number of people affected)

International Maritime Organization. *Guidelines for Formal Safety Assessment for Use in the International Maritime Organization Rule-Making Process*. (International Maritime Organization, 2002)
http://www.safedor.org/resources/1023-MEPC392.pdf

- The Formal Safety Assessment is a rational and systematic process for assessing the risks relating to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of the International Maritime Organization's options for reducing these risks.
- *Risk*: combination of the frequency and severity of the consequence

Pipeline Safety Trust. *Thinking About Risk.* (Pipeline Safety Trust, 2015)
http://pstrust.org/wp-content/uploads/2015/09/2015-PST-Briefing-Paper-06-Thinking-About-Risk.pdf

- Briefing paper discussing public perception and messaging of risk related to pipelines.
- *Risk*: made up of two different factors, both of which need to be carefully considered when deciding how risky an activity is. Those factors are the probability that an event will occur (the chance a pipeline will rupture or leak), and the possible consequences if it does.

Pooja Kungwani. *Risk Management – An Analytical Study*. (IOSR Journal of Business and Management, 2014)
http://iosrjournals.org/iosr-jbm/papers/Vol16-issue3/Version-3/K016338389.pdf

- Analysis of risk in financial market regulation
- *Risk*: potential of losing something of value, weighed against the potential to gain something of value. In finance, risk is the probability that an investment's actual return will be different than expected. This includes the possibility of losing some or all of the original investment.

Council of Canadian Academies. *Commercial Marine Shipping Accidents: Understanding the Risks in Canada. Workshop Report.* (Council of Canadian Academies, 2016)
http://www.scienceadvice.ca/en/assessments/completed/marineshippingrisks.aspx

- The Council of Canadian Academies convened an expert workshop to identify the risks associated with commercial marine shipping in major Canadian shipping regions.
- *Risk*: The potential for suffering harm or loss, where potential for harm is determined by the probability of a marine shipping incident or accident occurring, together with the nature and severity of the resulting impacts.

Paul Slovic. *Trust, Emotion, Sex, Politics, and Science: Surveying the Risk-Assessment Battlefield* (Risk Analysis, Vol. 19, No. 4, 1999)
http://www.soc.iastate.edu/sapp/soc415Psychological.html

- Psychological Risk Assessment
- The Psychological Risk Assessment recognizes that emotions guide risk assessments as much as do rational decisions about probability of harm and the balance of utilitarian costs and benefits. It brings people and their emotions into the risk assessment process. It is difficult, however, to translate emotional reactions into public risk policy.

Stanford Encyclopedia of Philosophy (2011)
https://plato.stanford.edu/entries/risk/#DefRis

- The Stanford Encyclopedia of Philosophy organizes scholars from around the world in philosophy and related disciplines to create and maintain an up-to-date reference work.

- *Risk*: In non-technical contexts, risk refers to situations in which it is possible but not certain that some undesirable event will occur. In technical contexts, the word has several more specialized uses and meanings:
    - Unwanted event which may or may not occur
    - Cause of an unwanted event which may or may not occur
    - Probability of an unwanted event which may or may not occur
    - Statistical expectation value of an unwanted event which may or may not occur
    - Fact that a decision is made under conditions of known probabilities (decision under risk as opposed to decision under uncertainty)

Nat. Res. Def. Council v. United States Nuclear Regulatory Comm'n, 222 U.S. App. D.C. 9 n.100, 685 F.2d 459, 478 (1982) (rev'd on other grounds)
https://supreme.justia.com/cases/federal/us/461/190/case.html

- This consolidated case brought by energy companies involved the continuing efforts of the Nuclear Regulatory Commission to establish a system by which to consider and disclose the environmental impact of the uranium fuel cycle in compliance with federal law.
- "*Risk*, in this context, refers to the product of the environmental damage that could occur and the probability of its occurrence. Thus, an environmental risk can be high if the probability is high that damage will occur, even if the damage itself would not be terribly severe. Alternatively, an environmental risk can be significant if the probability is low that damage will occur, but the possible damage, should it occur, would be severe."

Federal Law: 33 U.S.C.S. § 3301 – National Levee Safety Program
https://www.law.cornell.edu/uscode/text/33/3301

- Program administered by the United States Army Corps of Engineers to better understand, manage, and reduce the flood risks associated with levees
- *Risk*. The term "risk" means a measure of the probability and severity of undesirable consequences."

Federal Administrative Rule: Use of Locomotive Horns at Highway-Rail Grade Crossings (68 FR 70586)
https://www.gpo.gov/fdsys/pkg/FR-2004-02-06/pdf/04-2636.pdf

- The Federal Railroad Administration issued rules to requiring a locomotive horn be sounded while a train is approaching and entering a public highway-rail crossing.
- Crossing Corridor *Risk* Index means a number reflecting a measure of risk to the motoring public at public grade crossings along a rail corridor, calculated in accordance with the procedures in appendix D of this part, representing the average risk at each public crossing within the corridor. This risk level is determined by averaging among all public crossings within the corridor, the product of the number of predicted collisions per year and the predicted likelihood and severity of casualties resulting from those collisions at each public crossing within the corridor.

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