Aspects of Risk Tolerability, Manageable vs. Unmanageable Risks in Relation to Governance and Effective Leadership

Cesar Oboni[a], Franco Oboni[a*]
[a]Oboni Riskope Associates Inc., www.riskope.com
4-1620 Balsam Str., Vancouver, B.C., Canada
[*]Corresponding Author: foboni(a)riskope.com

ABSTRACT

Case studies of mishaps and accidents (Tailings Dams (TDs), Nuclear Reactors (NRs) and a Highway Tunnel) enable the discussion of risk social acceptability, estimates and communication applicable anywhere in the world.

The first part of the paper considers accidents' consequences only in terms of casualties; quantitative risks are compared to previously published acceptability criteria, showing unexpected results.

The paper shows how the type of consequences selection and combination can severely bias the perception of the results of a risk assessment. The paper discusses holistic losses and shows the shape of corporate tolerability thresholds.

The concept of social perception quantification, applicable to any accident, in any industry, while developing a holistic risk assessment, is illustrated. The perception gap between societal consequences and factual consequences is exposed, as it is a significant source of the pervasive mistrust in technical and scientific opinions.

The functional link between tolerability and manageable vs. unmanageable risks is explored to describe how governance and effective leadership are enhanced by proper risk evaluations, prioritization and a deep understanding of tolerability.

A communication strategy is suggested to convey to clients the correct message when dealing with "societal" consequences of private industry risks.

Keywords: Tailings Dams, Nuclear Reactors, Highway Tunnels, risk, social, acceptability, estimates, communication, casualties, perception, bias, tolerability, corporate, manageable, unmanageable, governance, leadership, prioritization, societal, ORE, FMEA, PIG.

1. Introduction

This paper builds on case studies of mishaps and accidents to discuss risks' social acceptability, estimates and communication in view of new projects world-wide and difficult choices humanity will have to make under demographic and climatic pressure.

Due to space limitation, the first part of the paper considers consequences of mishaps only in terms of casualties; thus Risk is defined as the product of the probability of failure (probability of an accident) by the related consequences expressed in casualties, leaving aside all other environmental and physical direct or indirect consequences.

Risks linked to Tailings Dams (TDs), Nuclear Reactors (NRs) and a Highway Tunnel (HT) catastrophic events are compared to well known, previously published societal acceptability criteria. A comparison of the acceptability of these risks is then carried out from a quantitative risk evaluation point of view showing unexpected results.

2. Comparing risks from various industries

Rates of world-wide TDs and NRs catastrophic accidents to date were empirically estimated (Oboni and Oboni, 2013) in a prior paper. The risk analysis of the Montblanc HT accident was the object of a research reported in Riskope's blog (Riskope, 2013). All these were compared to societal and technical acceptability thresholds to understand if present and foreseeable performances are aligned with expectations.

2.1 Tailings Dams

Table 1 summarizes the world-wide rate of failure (p_f) of TDs in the decades aroud '79, '99.

When (decade)	p_f	Approx p_f
Around '79	44/(3,500*10)	10^{-3}
Around '99	7/35,000	$2*10^{-4}$

Table 1: Summary of historic rates of failure (p_f) of Tailings dams around the world.

If we consider, for comparison, the hydro dams failures in the decades around '89 and '99, based on an “average number of dams” of 30,000, we get $p_f = 3*10^{-6}$ to 10^{-5}, in good agreement with the common understanding and empirical knowledge that TDs are generally of “lesser quality” than hydro dams. Interestingly many different industries around the world consider values below 10^{-6} to 10^{-5} as the boundary of what is humanly credible (meaning that below that range of probability an event is generally considered “incredible”).

Based on historic records of publicly available catastrophic failure records Casualties for TDs were estimated to a minimum of nil, a maximum of ~500, and an expected value of ~80 casualties. Mediatic consequences have been often considerable, sometimes leading dam's owner bankruptcy or independence loss. However, there has been to date no known global regulatory rejection/ forced withdraw of mining operations' license to operate (however, projects world-wide have been abandoned because of public opinion pressure).

2.2 Nuclear Reactor accidents

As of Feb. 2, 2012, 435 nuclear power-plant units were in operation in 31 countries. The cumulative nuclear reactor operating experience amounted to 14,745 years. The world has seen the occurrence of a number of major nuclear reactors accidents (rated 5 and above on the International Nuclear Event Scale by the International Atomic Energy Agency), as displayed in Table 2. Fukushima Daiichi was considered as one accident (Oboni and Oboni, 2013), although more than one reactor was involved and there has been a recurrence of new accidents on site, to ensure the list is made of “independent” accidents. Assuming seven accidents, the “historic” world average rate of Scale 5+ accidents was $4.75*10^{-4}$ Scale 5+ accident/annum by Feb 2, 2012.

Level 5	Level 6	Level 7
Accident with wider consequences	Serious accident	Major accident
First Chalk River (1952) Windscale (1957), Lucens (1969), Three Miles Island (1979)	Kyshtym (1957)	Chernobyl (1986) Fukushima (2011)

Table 2: Worldwide accident of Scale 5+

This value is rather unexpected as it falls well within the realm of credibility and within the range of TDs. The surprise is even higher when considering the high level of regulation of the nuclear industry compared to the relatively unregulated mining industry.

Casualties for Nuclear 5+ accidents are estimated to a minimum of nil and a maximum of 3,500 casualties, with a “best estimate” at 890 casualties (Oboni and Oboni, 2013). Mediatic/political consequences have been staggering, including regulatory decision to stop operations/new projects in some countries.

2.3 Risk quantification of a specific accident: Mont Blanc tunnel

The Mont Blanc Tunnel was completed in 1965 and used for 34 years before a tragic accident (39 casualties) occurred due to a truck fire. Previously there had been 16 other truck fires in the tunnel, always extinguished on the spot by the drivers. The heavy truck traffic was estimated at 8.77 Mkm/yr (million kilometres per year).

In 1998 the victims' (casualties)/Bkm (Billion kilometres) expected rate due to “classic” trucks road accidents could have been estimated at 0.022 victims/yr for accidents “on trucks” , respectively 0.22 victims/yr for accidents “against the truck”. We will note that the last number seems rather unreasonably high for a tunnel where passing is forbidden, and speed is controlled. Thus, we will consider this as an extreme upper bound of the probability of one casualty as we prefer to use ranges rather than censoring results by arbitrary narrowing them.

Another way of framing probabilities and related risks would have been to consider the 16 actual fires events in 34 years, which could be considered near misses of a major fire, as they produced no casualties. These numbers yield an estimate of 0.35 for the probability to see one or more accidents within next year. Again, the 16/34 frequency is certainly too high so, by using Frank's Pyramid (Bird, Germain, 1985), recognizing its limitations, the probability of a serious accidents, can be evaluated at p=0.015 in the coming year.

The accident was vividly echoed in international media, and ultimately brought long lasting socio-political consequences throughout Europe.

3. Acceptability criteria and codes

3.1 Chemical Industry

Looking back in time, Wilson and Comar (Comar, 1987, Wilson, 1984), then in the field of chemical industry Renshaw (Renshaw, 1990) defined simple societal risk acceptability criteria as described in Table 3 and depicted in Figure 1.

Author	Units	Unacceptable Risk/ Upper Bound	Negligible Risk/ Lower Bound
Renshaw	Probabilities of Fatality of one Individual per Year of Exposure to the Risk	10^{-5}	10^{-7}
Comar		10^{-4}	10^{-5}
Wilson		10^{-3}	10^{-6}
Renshaw	Probabilities of Fatality of Ten Individuals per Year	10^{-5}	10^{-7}

Table 3: Renshaw, Comar, and Wilson unacceptable and negligible, risks thresholds.

The application of these criteria is easily understood with an example. If a limiting probability of 10^{-5} (Renshaw acceptability limit) is selected in a country with approximately 60 millions inhabitants like France, Italy or the United Kingdom, it leads to accepting a hazard potentially generating 600 fatalities per year, provided fatalities occur for one to ten individuals at a time.

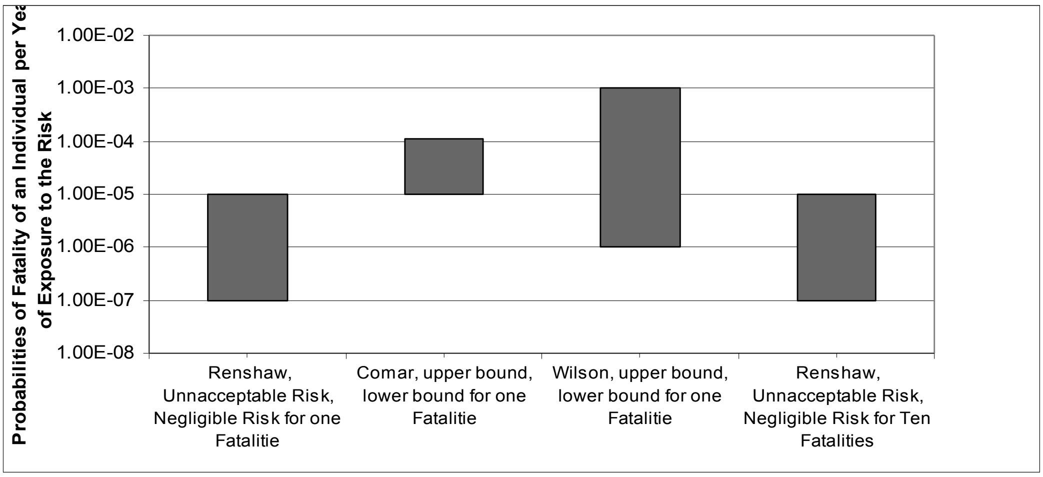

Figure 1. Renshaw, Comar, and Wilson unacceptable and negligible, risks thresholds.

That number is roughly ten times lower than traffic related casualties in Italy in 1994 (ISTAT, Italy), respectively 5,232 for France in 2004 (European Conference of Ministers of Transports, 2005), or five times lower than the 2004 observed 3,221

fatalities in the U.K. (Department for transport Scottish executive national assembly for Wales, 2006). Thus the limiting value for Renshaw is totally passed by reality in the three countries. The traffic risk should be considered as unacceptable. Instead, if the Comar and Wilson criteria were used, then the risk would be considered acceptable.
Interestingly none of the criteria cited above make a distinction between voluntary risks and involuntary risks and if, on one hand, governments make huge efforts to reduce the fatality count in their respective jurisdictions, on the other, the public keeps using (and abusing) cars, with no (or very little) consideration to risks.

3.2 Federal Highway Administration societal tolerability thresholds

Baecher (1987) showed how to select design factors of safety by comparing nominal probabilities of failure with previously derived (R.V. Whitman, 1984 & G. Morgan, L. Lave, 1990) accepted (i.e., historical) rates of failure of other civil facilities (Fig.2). Baecher noted that financial and life loss typically occur together, and the double scale shown in his original figure (Fig. 2) was not intended to imply a tradeoff of dollars vs. Lives. Today human lives are generally discussed in terms of Willingness to Pay (WTP) (Marin, 1992, Lee Jones, 2004) to avoid any misunderstanding.

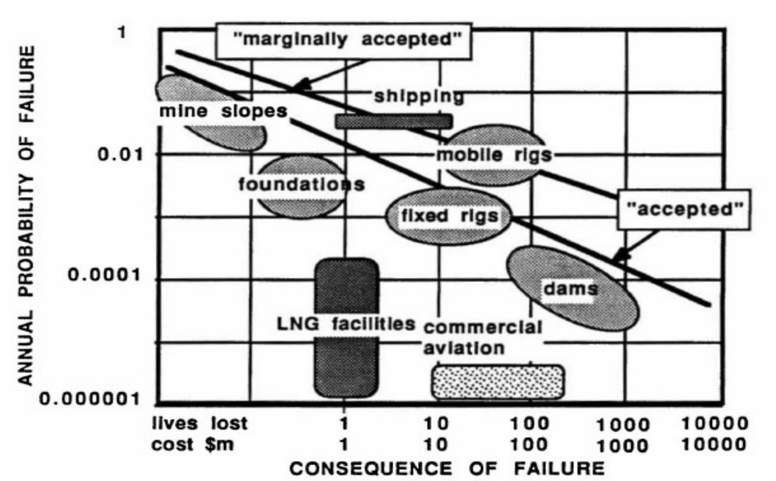

Figure 2. Empirical rates of failure for civil facilities.

3.3 F-N Curves for nuclear hazards and the aerospace industries

F-N curves were originally developed for NRs and the aerospace industry (Kendall et al., 1977) to illustrate thresholds that reflect societal aversion to multiple fatalities during a single catastrophic event.

The graph (Fig. 3) is subdivided into four areas:

- unacceptable risk;
- tolerable risk that should be reduced further if practicable according to the As Low As Reasonably Practicable (ALARP) principle;
- broadly acceptable risk; and
- a region of very low probability but with the potential for >1000 fatalities that require intense scrutiny.

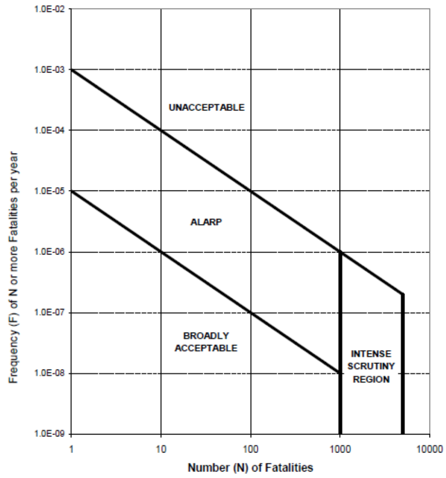

Figure 3. F-N Curve for Evaluating Societal Risk.

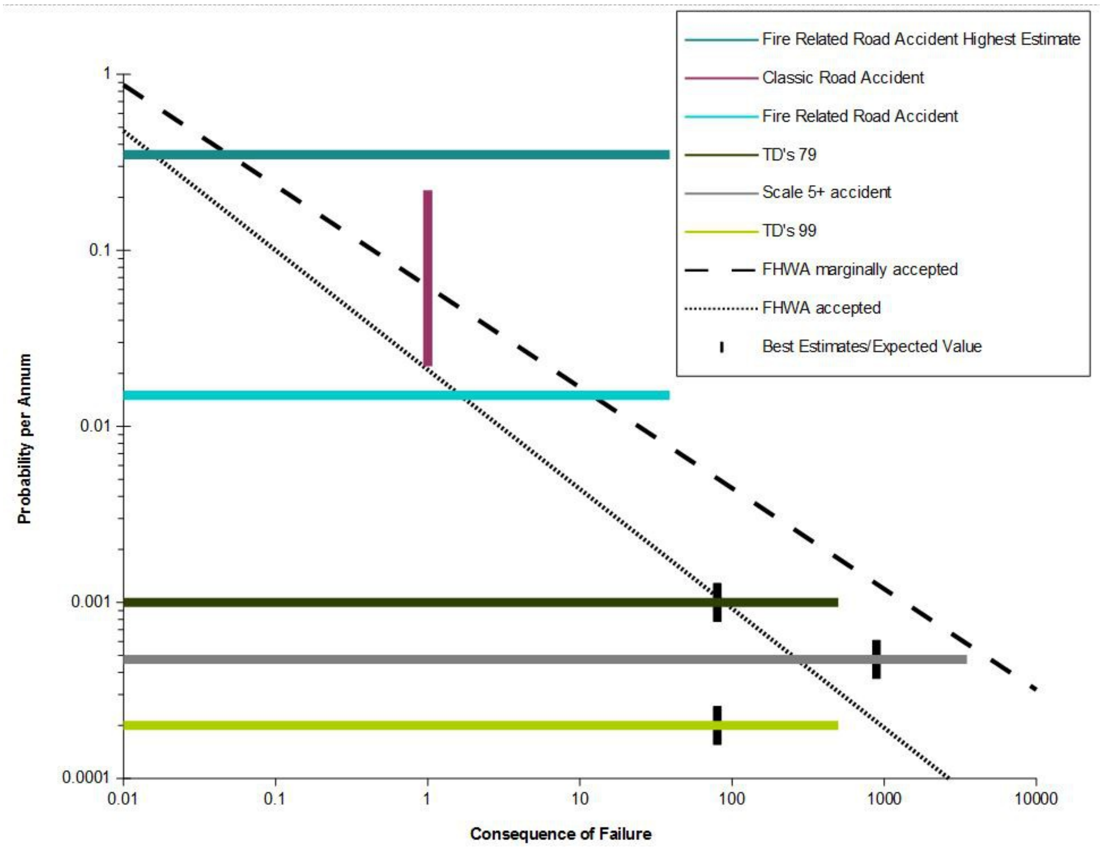

Figure 4. Various accidents (considered consequences are casualties only) compared to Whitman societal tolerability curves (R.V. Whitman, 1984 & G. Morgan, L. Lave, 1990). The black vertical traits represent the position of the average victims estimates (Oboni, Oboni, 2013).

From the perspective of potential loss of life from, for example, a landslide, new residential developments are typically approved if it can be demonstrated that the landslide risk falls in the ALARP or broadly acceptable regions of a F-N curve (Porter , Morgenstern, 2013) (Fig.3).

4. Risks Comparisons (in term of lives losses)

The values derived from TDs, Nuclear Reactors accidents and the Mont Blanc Tunnel fire can now be plotted on a p-C graph also displaying societal tolerability levels (Fig. 4).

The following can be inferred from Figure 4:

- In the '79 decade TDs accidents were sliding above societal tolerability and the mining industry reacted, mostly under mediatic pressure, to reduce TDs risks to a societally tolerable level in term of losses of lives.

- The expected value of NRs risks were, as of Feb 2012, above the lower societal tolerabiliy and governments (Germany, Italy, Japan) reacted sharply at the last accident.

- Traffic accidents (with trucks involved) and risk estimates of HTs related accidents were high (in term of lives losses) and governements (EU), in general, sharply reacted to mitigate them with infrastructural investments and awareness/communication campaigns.

This tends to prove that Whitman thresholds are still valid today and accidents/industries that exceed the thresholds get instinctively societally "reprimanded". As a matter of fact, as far as the Authoras know, goverments and regulatory agencies very seldom perform the simple analysis we have presented above and their reactions are societally-perception driven rather than based on formal evaluations.

5. Other types of consequences and their combination

If we consider the Mont Blanc HT accident as an example, consequences were tragic and complex:

- 39 casualties,
- structural damages to the tunnel itself,
- legal costs and liabilities, and
- a very long and costly business interruption which congested traffic in an area spanning a radius of over 300km in central Europe.

Despite the evidence of complex consequences in many accidents, old fashioned, common practice risk assessments based on Probability Impact Graphs (PIGs, matrix approaches, FMEA (Failure Mode Effect Analysis)) mostly reduce consequences to one metric (for example human life) and force users to "select the worst" among two or three families, often Health & Safety, Environmental, Direct Operation (Oboni, Oboni, 2012). In real life consequences components happen with "AND", and not as "OR" as common practice risk assessment tend to consider.

A recent decision bearing on a highly debated “perpetuity” environmental rehabilitation required by very large toxic material dumps in Canada (Reviewboard, 2012) defined what a modern risk assessment should include, based on public hearings results.

Based on the above it becomes clear that including partial components of the consequences such as:

- Biological Impacts and Land Use,
- Regulatory Impacts and Censure,
- Public Concern and Image,
- Health and Safety,
- Direct and Indirect Costs,

is a better way which brings credibilty and add transparency to a risk assessment, i.e. a way to reduce public distrust toward risk assessments.

6. Social perceptions quantification

Very often hazards bear a significant portion of public perception consequences, possibly leading to increased risk levels resulting from boycotts, vandalism, eco-terrorism, and other more or less legal actions.

It is very possible that a tolerable risk (one that has p,C below tolerability) gets “shifted to intolerable grounds” based on a consequence amplification effect due to perception.

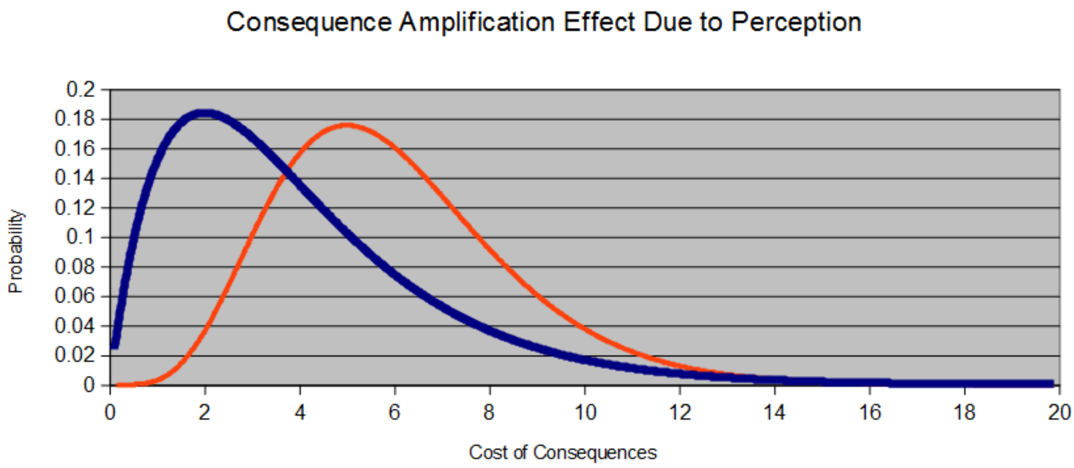

Figure 5. A risk scenario (blue curve) may have a large crisis potential and become shifted to the right, leading to the Red curve (costlier consequences).

There is of course a part of judgment to be used by analysts, but in the Authors' experience the following procedure can be applied:

1) Use a guided judgement system (see Figure 6) to decide if the potential accident will lead to high levels of local, regional, national, international scrutiny.

2) If the "factual consequences" of the potential accident and the probability lead to an apparently tolerable risk, but the level of scrutiny is significant, chances are the risk will be pushed to the tolerability threshold (and possibly beyond) by social perception amplification.

3) It is now possible to quantify the "social perception" effect by evaluating the multiplier between "factual risk" and the amplified risk.

4) Define appropriate mitigation or, if unmanageable (see Section 8 for the definition of unmanageable), shift your strategy.

Reach of Public Scrutiny	Level of Public Scrutiny: Negligble	Low	High	Intense
Advocacy / NGO's		Lobby State and Federal Governments to close Mine	Legal procedings initiated to limit or close operations	Illegal activities to block operations
Local News Media		Negative article in Alaskan newspaper or TV program	Series of unfavorable reports or articles on the operation	Negative articles that challenge government agencies
International News Media		Newswire article of a incident at the operation	Series of unfavorable reports or articles on the operation	Inter. Media come to the region to investigate the operation
Local Government		A meeting to review the situation/incident is requested	Lobby for closure of the Mine by State or Federal authorities	Closure of operation through NANA
State/Federal Government	A meeting to review incidents is requested by authorities	Fines are imposed for viloations	A review of existing operating permits is initiated; Major changes required	Withdrawn operating permits to cause closure of Mine
Investors	Incident is noted by inventment analysts	Incident results in a negative change in stock price	Major investors raise concerns & questions with Board of Directors	Inability for TC to obtain corporate financing for other projects

Tolerable	Difficult	Un-Acceptable

Figure 6. Simplified Model of Public Reactions Impact.

7. Monetary loss and shape of tolerability thresholds

When moving the focus of an analysis from societal acceptability to corporate acceptability, the shape of the tolerability thresholds changes. This has been systematically observed across the world during a two decades long privately funded research by the Authors. Instead of the "straight lines (in log-log scale)" displayed in Fig. 2, or the "grossly truncated" of Fig. 3, as we can see in Figure 7 there is a threshold in the consequences, different for each entity, corporate, community or governemental, that will always be considered intolerable no matter how little the probability of occurrence.

This "capping" phenomenon can be explained in 2 ways.

1) The tolerable level suddenly tends to zero once a loss volume is exceeded. Most of the time there is a limiting value of consequences that will be seen as intolerable because the outcome is so devastating that it will lead to a company's ruin or large casualties. Companies often perceive that, for those limiting losses, no matter how low the probability, the chance the loss could occur "tomorrow" renders it intolerable.

2) The probability of the losses is entirely disregarded. The neglect of probability, a well know type of cognitive bias, is the human tendency to completely disregard probabilities when making a decision under uncertainty and is one simple way in which people regularly violate the normative rules for decision making. (Small risks are typically either neglected entirely or hugely overrated, the continuum between the extremes is ignored.) As media and political people make decisions they tend, driven by this bias, to look only at the outcome and disregard the probability.

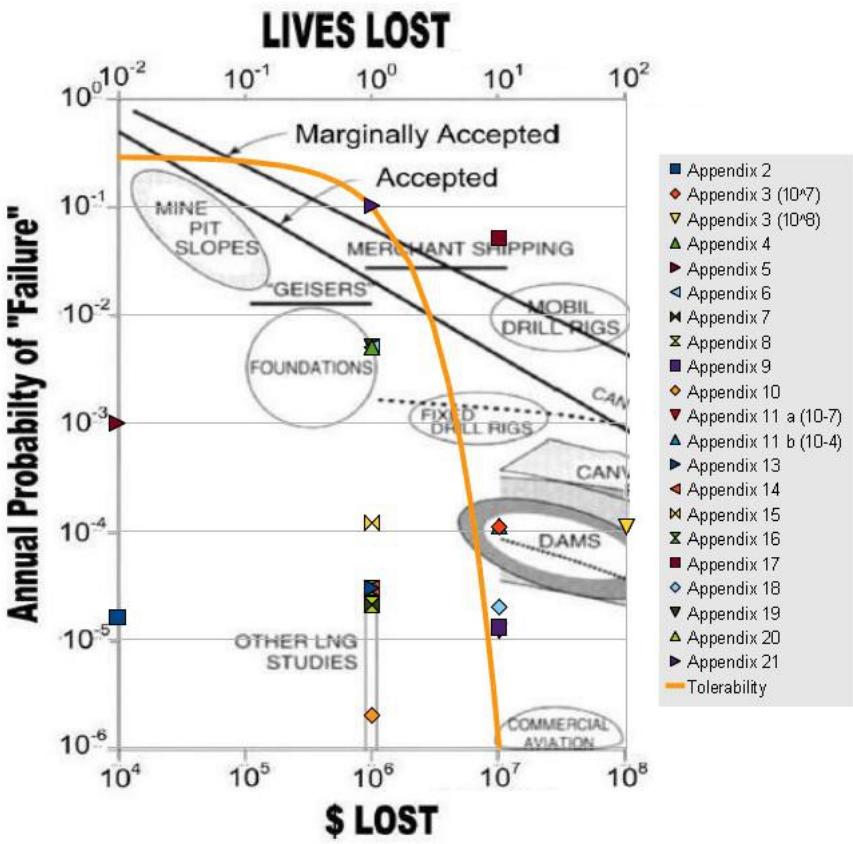

Figure 7. A practical "general" tolerability (orange curve) compared to Whitman's societal tolerabilities (See Fig. 2). Various tolerable and untolerable risk scenarios are shown, from a real operational risk assessment. (In compliance with the explanation in Section 3.2, the double scale (Lives, $) was not intended to imply a tradeoff of dollars vs. Lives. Today human lives are generally considered in terms of Willingness to Pay (WTP) (Marin, 1992, Lee Jones, 2004) to avoid any misunderstanding.)

8. Unmanageable vs. managable risks

By using any of the explicit tolerability thresholds discussed earlier it is possible to give a transparent definition of what constitutes a manageable risk: if a risk above tolerability (probability, consequence) can be brought under the selected tolerability threshold by mitigative investments that still preserve the economic livelihood of a company, then that risk is manageable.

The key element here is a corporate/government choice of what level of mitigative investment preserves the economic livelihood of an entity. If the risk cannot be brought under tolerability as described, then it has to be considered unmanageable. Unmanageable risks cannot be mitigated, they require strategic shifts in the corporation/government.

For example:

- TDs have been brought under tolerability by mitigating their risks, i.e. building better dams, monitoring and maintaining them to higher standards. TDs constitute, generally and as a whole, a manageable risk.

- Tunnel accidents have been mitigated by changing traffic rules, enhancing ventilation and fire estinguishing means, so they are also manageable.

- The Nuclear Reactors risks have been managed to date with *moratoria* and governmental statements indicating the willingness to shift to other sources of energy, thus giving the impression that they are considered unmanageable risks and they require stretegc shifts.

Figure 8 shows the results from a real life large corporate risk assessment where operational as well as corporate risks (i.e. economic & financial, geopolitical, social, infrastructural & environmental, business) were evaluated. Many scenarios are depicted with the "best estimate" of p,C, but others are shown as segments, in an attempt to introduce large uncertainties on the evaluation of p,C.

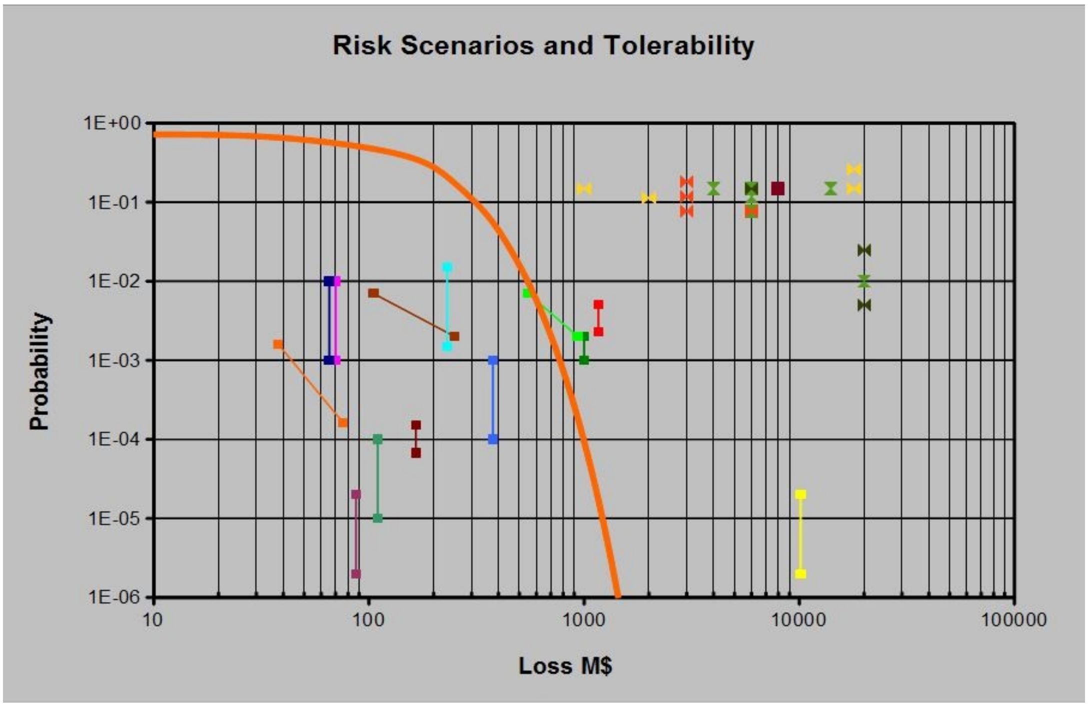

Figure 8. results from a real life large corporate risk assessment where operational as well as corporate risks (i.e. economic & financial, geopolitical, social, infrastructural & environmental, business) have been evaluated. Top-right Risks are un manageable.

It should be noted that in many studies the corporate tolerability itself is depicted as a broad band, not a line, to include uncertainties on its definition (optimistic vs. pessimistic tolerability).

Thanks to these transparent and rational approaches it becomes possible to envision clear risk communication plans to preventatively mitigate public hostility against a corporation and/or investor-management conflicts. With this objective in mind, it is vital to separately develop upper Management and corporate's/investor tolerability thresholds, then compare them in an open and transparent dialogue which will help mitigation decisions "alignment" resulting in mutual protection and maximization of benefits for all parties.

Generally, once upper Management have this type of results available, they see that they cannot limit themselves to deal exclusively with arbitrarily or gut-feeling selected risks which seem "very large/critical", but need to have each risk defined and compared to their carefully defined acceptable threshold. As a matter of fact, there are operational risks that can jeopardize the whole corporation, and conversely, corporate risks that may be benign.

The methodologies described in this paper support with transparency Board/Government decisions to intervene with mitigations at any level after formal decision making, instead than relying on intuition and guts feeling, as performed by many corporations' Boards of Directors or Governmental Agencies around the world.

To streamline the process and allow regular updates the Authors deploy commercially the methodologies described in this paper as "Optimum Risk Estimates" (ORE, (c)Oboni Riskope Associates Inc.). On top of the results shown in this paper ORE allows rational prioritization of risk portfolios and has been deployed to date on four continents, for industries going from transportation, suppliers, energy, natural resources, defence.

The chances Management would adopt a selection by consequences are very high (see Section 7 for an explanation) if instead of using the methodologies presented herein and having a proper rational assessment, Management had in their hands a common practice (matrix based) risk assessment result (PIG/FMEA) where the tolerability has not been transparently developed and prioritization is based on arbitrarily placed colours in a "binning" exercise (Oboni Oboni, 2012).

9. Conclusions

Perception of risks related to industrial accidents can be severely biased if consequences are censored and skewed either because the risk assessment method is too simplistic (PIGs, FMEA), or if the analyst or the client decide to apply too strict "facts driven" approaches or oversimplified metric for consequences.

Yet, numerous recent examples ranging from mining to tunnels, nuclear, railroads (Lac Megantic RR accident in Canada), etc. have shown that the "fact driven" consequences evaluations approach will lead its user to unsustainable stances.

After showing that it is possible to "quantify social perception" and include it in a rational risk assessment framework, this paper suggests a communication strategy to be implemented when discussing tactical, operational and corporate risks.

The benefits for the clients of any type, corporate, community, project or a government, are very significant in terms of clarity and transparency in decision making, and clear prioritization of risk portfolios can be performed as an additional step (www.riskope.com).

By using properly defined tolerability and abiding to basic definitions it is possible to transparently define what risks are manageable and which ones are un-manageable.

It is vital to separately develop upper Management and corporate's/investor tolerability thresholds, then compare them in an open and transparent dialogue which will help mitigation decisions "alignment" resulting in mutual protection and maximization of benefits for all parties.

ERM common practices based on PIGs (Probability Impact Graphs), FMEA are not sufficient to properly represent risks and support decision making: their multiple scales and arbitrarily bound matrices, colours and indices, lead to blurred ERM registers and risk evaluations which may very well, sooner or later, be challenged in courts.

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