# Is it True that PIGs Fly when Evaluating Risks of Tailings Management Systems?

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ABSTRACT: In many cases risk assessment of complex tailings systems leads to: 1) Management being overwhelmed by so many "medium/orange" risks and 2) Management not receiving proper guidance in the allotment of mitigative funds to new and old scenarios. "Risk Matrices", Probability-Impact Graphs (PIGs), and "Heat Maps" generally used in mining Risk Assessments, present critical and potentially damaging intrinsic problems, recognized now by Academia and consultants from different countries, including the authors. When looking at Risk Assessments of operations, plants and networks, this paper shows that PIGs (we will use the acronym generically, to also include risk matrices and heat maps) do not fly. They are misleading and actually constitute a liability. In the paper we show first the fallacies of PIGs, ("Risk Matrices", Probability-Impact Graphs (PIGs), and "Heat Maps") when used for mining waste or tailings management, then we describe two mining case studies where the rational approach called Optimum Risk Estimates (ORE) has been used. Optimum Risk Estimates (ORE) overcome the problems and fallacies of PIGs. The results are discussed in detail, showing how all the intrinsic problems and liabilities of PIGs are solved by upgrading existing corporate Risk Register, and how the ORE approach covers management requirements and allows steering operations, projects and corporations toward a rational, defensible and transparent mitigative stance. ORE are the first and most important step in increasing the resilience of complex systems, they have been deployed in mining, but also to nation/system-wide risk management approaches in Europe.

## 1 INTRODUCTION

This paper shows the deployment of a method developed in over twenty years of world-wide Risk Management practice, called Optimum Risk Estimates (ORE)© Oboni Riskope Associates Inc. ORE can solve difficulties and liabilities brought to Tailings Management Systems by Risk Management approaches using "Risk Matrices", Probability-Impact Graphs, and "Heat Maps". We will use the acronym "PIGs" generically, to include risk matrices and heat maps. PIGs are indeed applied ubiquitously by Risk practitioners, despite critical and potentially damaging intrinsic problems flawing them.

Riskope is not the only entity to reckon this. Academia, other consultants around the world are indeed starting to or have already published papers going in the same direction (See next Section). As a result, we can affirm that "PIGs do not fly"; they are misleading and could get their users straight in front of a Judge in a Court of Law. The benefits brought by using the ORE methodology are explained in this paper using real life Tailings Risk Assessments for existing mining operations. With Oboni Risk Associate's ORE it is possible to upgrade an existing corporate Risk Register steering operations and projects toward a rational, defensible and transparent stance.

## 2 OUR JUDGEMENTS ARE CLOUDED BY PREJUDICES AND MISCONCEPTIONS

### 2.1 *Limitations and Flaws of Common Approaches*

Over the last five decades or so, the risk management community has settled on representing the results of Risk Assessments with PIGs. PIGs are ubiquitous, but have a number of staggering intrinsic conceptual errors, with potentially dramatic negative consequences on their users.

In the last decade technical literature has begun to specifically address PIGs logical and mathematical limitations (Cox *et al.* 2005, Cox 2008, Cresswell, Hubbard 2009, Chapman & Ward 2011). Reportedly, the debate has recently found its way to the UK's Association for Project Management Risk Special Interest Group; Chapman and Ward discuss this debate in their book. The quoted literature shows that little research rigorously validates PIGs performance at improving risk management decisions and exposes PIGs poor resolution and errors. Typical risk matrices can only correctly and unambiguously compare a small fraction, reportedly less than 10%, of randomly selected pairs of hazards. Furthermore, they can assign identical ratings to quantitatively very different risks, a phenomena often referred to as "range compression" and can mistakenly assign higher qualitative ratings to quantitatively smaller risks. These inaccuracies can lead to mistaken resource allocation.

It also appears that the meaning of a risk matrix may be far from transparent, despite its simple appearance. In general, risk comparisons in a risk matrix require explanations—seldom or never provided in practice—about the risk attitude and subjective judgments used by those who constructed it. In particular, as consequences are generally random variables with a large range, then there may be no guarantee that risks receiving higher risk ratings in a risk matrix are actually greater than risks that receive lower ratings. That is most likely why NASA (NASA 2007) stated in their Systems Engineering Handbook that risk matrices are not an assessment tool, but can facilitate risk discussions and help track the status and effects of risk handling efforts, and communicate risk status information. NASA then quotes more than five limitations similar to those described above.

### 2.2 *A Glimpse into Behavioural Sciences*

The continued "main stream" reliance of using inappropriate techniques like PIGs, and being satisfied with their results, or, using intuition to correct PIGs' evident fallacies, is simply another manifestation of what Kahneman and Tversky explored when they examined the ways Humans have found to introduce irrelevant criteria in decision-making (Kahneman & Tversky 1979, quoted in Oboni & Oboni 2007).

As a matter of fact Kahneman and Tversky have explored in detail how human judgment can be distorted when making decisions under uncertainty: humans tend to be risk-averse when facing the prospect of a gain, and paradoxically risk-prone when facing the prospect of a loss (even if the loss is almost certain to occur)! So, using improper methods like PIGs, which almost surely will lead to confusion, losses, and poor planning sits well with "main stream" human nature, as does disregarding what a reputable scientific group like NASA spells very clearly in a manual that allowed Man to go to the Moon.

Once we realize that using PIGs is no more than a help for discussions, is not an assessment tool, (NASA, 2007) and using them leads at best to wasting precious mitigative funds (Cox 2008, Hubbard 2009, Chapman & Ward 2011), the whole idea of being able to correct existing PIGs, as they stand in most industries, comes out as a clear winner: by deploying rational prioritization we give a rest to our scientifically proven fallacious intuition, and allow our rational ego to make better informed decisions.

## 3 ARBITRARY SELECTIONS IN RISK MANAGEMENT ARE A LIABILITY

Based on the discussion above, we can foresee that soon cases will be challenged in Courts of Law against companies using PIGs for their risk assessments and the resulting decisions. The questions that could be asked to those companies will be horribly embarrassing and very damaging, as they will tend to prove that the approach constituted a professional negligence, due to blatant breach of the Duty of Care. Here are a few summarized examples of questions that could be asked (See http://foboni.wordpress.com/2012/03/01/arbitrary-selections-in-risk-management-are-a-liability/ for a complete discussion on this subject.):

1. So, on which basis did you decide that the probability of the event was “medium”, or whatever your PIG shows, and more importantly, why did you neglect to use any of the methods, published from the ’80s on about (subjective, expert driven) approximations of probabilities?
2. What is the basis for defining consequence (loss) classes in your PIG? ...
3. Which studies did you develop to define the various class limits of likelihood, and losses? On which basis did you select those limits?
4. Why did you limit the highest class to -x- casualties and -y- millions? ...
5. So, did you use PIGs just because every one uses them? ...
6. Which criteria did you use to select the colours of your cells, which correspond to various levels of criticality? What criteria did you use to define those levels of criticality?
7. There are tolerability criteria published since the mid ’60s. How come your colour threshold does not match any known tolerability criteria, ....?
8. Using “credible scenario” is a censoring decision. How come you felt entitled to censor your analysis? ...
9. Using “average p, C (loss)” is a biasing decision. ....

We doubt a PIGs user will be feeling in a strong position to further argue the case. The next sections will show how to avoid these pitfalls and their unpleasant consequences.

## 4 CASE STUDY 1

We will use, for this first Case Study, Operation Ten (OT) belonging to our client AAA Inc. (AAA) (names, locations and risk names have been altered to respect client's confidentiality), a medium sized mining operation. Geographic location, mining type and product do not matter for this discussion.

OT's Management formulated an explicit request to the Authors to deliver a risk based decision making (RBDM) support study: “The assessment will consider the particular environment, specific location and activities of OT to envision mitigating its risks to a tolerable level and to establish a conceptual framework to support decisions regarding its future conditions. In particular, the Action Plan will be mainly targeted to OT's decision makers and should answer practical questions... ”.

The study started by analyzing the Status Quo, including the level of awareness, understanding and sophistication of OT/AAA and concluded that they were at par with the international consensus in the area of risk assessment. OT was using PIGs and it became obvious that Management was not getting the guidance they were seeking. Riskope's ORE was deployed as described in the following sections.

### 4.1 *Status Quo Analysis: PIGs Approach Before ORE Deployment*

OT used PIGs to prioritize risks compiled in a risk register (prepared with a commercial software) in view of their management. OT's PIG was a 5x5 classes (frequency x severity) matrix defined as follows.

| Classification | Level | Characterization |
|---|---|---|
| Frequency | 1 | 1 failure in over 100 years |
| | 2 | 1 failure in 10 to 100 years |
| | 3 | 1 failure in 5 to 10 years |
| | 4 | 1 failure in 1 to 5 years |
| | 5 | more than 1 failure per year |
| Severity | 1 | $0 to $1,000,000 in costs |
| | 2 | $1,000,000 to $5,000,000 in costs |

| | |
|---|---|
| 3 | $5,000,000 to $15,000,000 in costs |
| 4 | $15,000,000 to $50,000,000 in costs |
| 5 | more than $50,000,000 in costs |

OT had selected four stepped thresholds of attention (criticality) for risks in the matrix: Severe, High, Medium, Low. A rule based on the value of the multiplication between the frequency and the severity indexes had been established as follows.

| | | Min | Max | Risk Rating | Freq * Severity |
|---|---|---|---|---|---|
| Severe | S | 20 | 25 | S = Severe | > 19 |
| High | H | 10 | 19 | H = High | 10 TO 19 |
| Medium | M | 4 | 9 | M = Medium | 4 TO 9 |
| Low | L | 0 | 3 | L = Low | < 4 |

OT's 50 extant risks scenarios had been prioritized as follows: 0 Severe, 14 High, 25 Medium and 11 Low risks. Do you remember the old saying that you should “never cry wolf”? Well, with 14 High, 25 Medium, Management's reaction was to say: “too many to cope, let's wait or let's give equal attention to all”, which was intrinsically hazardous because it gave a “false completeness” sense of security. As discussed earlier, PIGs do not have the ability to deliver clear guidance in the selection of risks priorities, or to test the adequacy of mitigation plans (See http://foboni.wordpress.com/2010/06/08/bp-crisis-rational-analysis-what-bp-did-not-perform/ for more details.). As a matter of fact, the problem of expenditure on safety measures is one of allocation of resources and cost-effectiveness which has to be based on the whole spectrum of possible events, instead of the Maximum Credible Event, ALE (Annual Loss Expected) or some other deterministic parameter (Lees, 1980).

This inappropriate funds allotment becomes even more problematic when, as it happens in economic downturns, mitigative budgets tend to shrink.

### 4.2 *ORE Deployment: Converting Risk Register Data into Usable Data*

A series of four proprietary questions was used in a facilitated workshop with key personnel to allow the definition of tolerability. Then OT's matrix frequencies' indexes were converted into probabilities and the consequences indexes were turned back into monetary losses. Once the indexes were eliminated it became possible to evaluate “real” risks, as the product of probability and consequences, expressed in monetary terms, and plot them in a probability-Consequences (Losses) diagram.

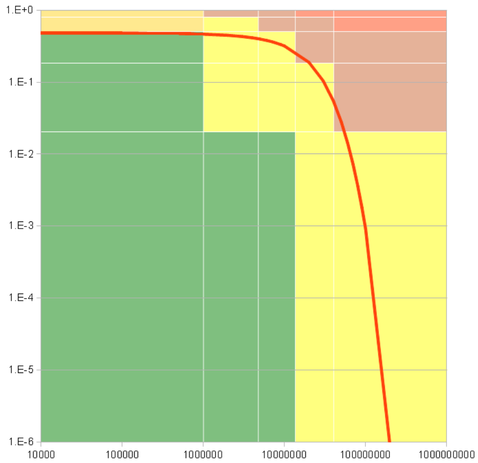


Figure 1. The original matrix cells are shown on a log-log probability-consequences plot, together with the newly developed OT's tolerability curve.

That diagram (Probability (vertical axis, a number between nil and one)- Consequences (horizontal axis, dollars)) is displayed in Figure 1, and the newly defined tolerability curve plugged in. As it can be noted, the curve follows the steps of the matrix threshold (yellow-red limit) with classes displayed here in a log-log scale. The "total" risk for each scenario can be calculated, and when applicable, it is possible to evaluate which portion of that risk lies above the tolerability as depicted in Figure 2.

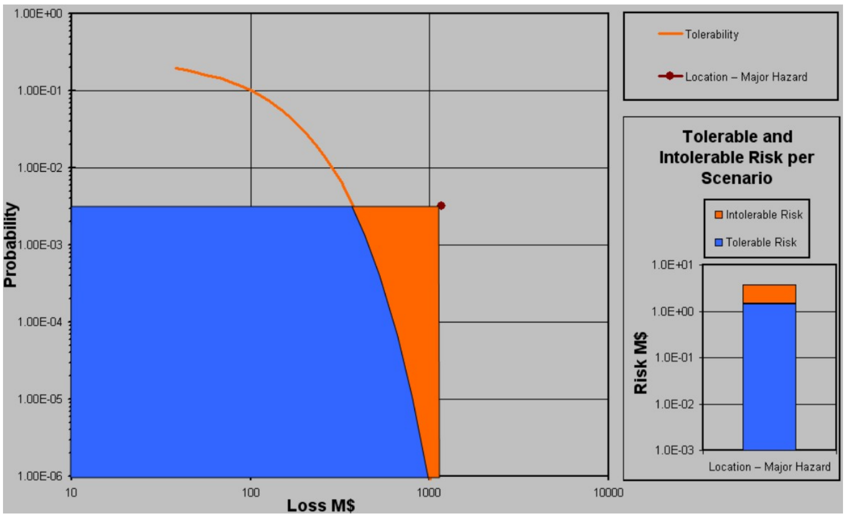


Figure 2. When probability and consequences of a scenario are evaluated, the total risk is equal to (p*C). The blue area is the tolerable part of that scenario, the orange part is the intolerable portion. NB: the log-log scale requires some attention when interpreting the relative size of surfaces.

The bar graph in Figure 3 shows, as an example, a small portion of the risks from OT's original Risk Register, with the tolerable part in blue, the intolerable part in orange, and the total risk equal to the sum of the blue and orange bars for each scenario.

If we plot risks from highest down to lowest, Figure 4 shows the top 20 risks. We can see that even though some risks scenarios are overall higher (blue and orange bar), the size of the intolerable part (orange bar) may lead to a completely different prioritization, resulting, of course, in a different respective allocation of mitigative resources.

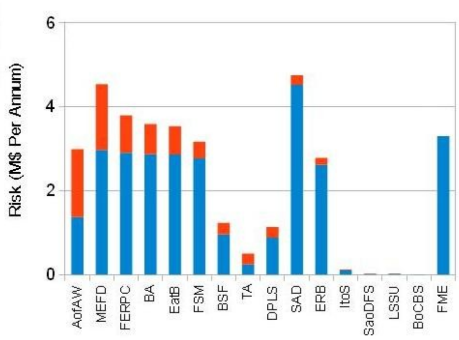


Figure 3. A small part of OT's original Risk Register, with, for each scenario, a tolerable and intolerable risk partition.

## 4.3 *Rational Prioritization of Risks*

Rational and transparent prioritization is achieved when risks (above tolerability) are ranked in decreasing order of the intolerable portion (only the orange bars), even if the overall risk is higher, leading to the graph displayed in Figure 5.

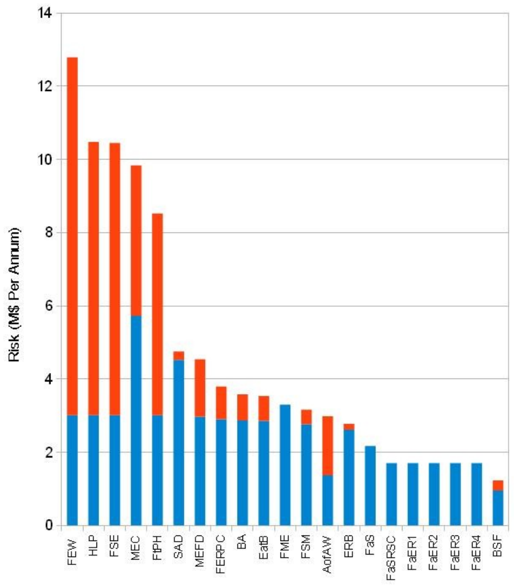


Figure 4. OT's largest total risks, in decreasing order from left to right.

At this point it becomes interesting to compare the relative value of the risks' intolerable part for the allocation of resources regarding mitigations measures.

We can see from Figure 6 that five OT's scenarios count for 83% of the total intolerable risks. We could therefore state, at first sight, that for every dollar spend for mitigations approximately 80 cents should be spent in relative proportions for the 5 "top intolerable" risks, then the remaining 20 cents should be split amongst the next 15 risks.

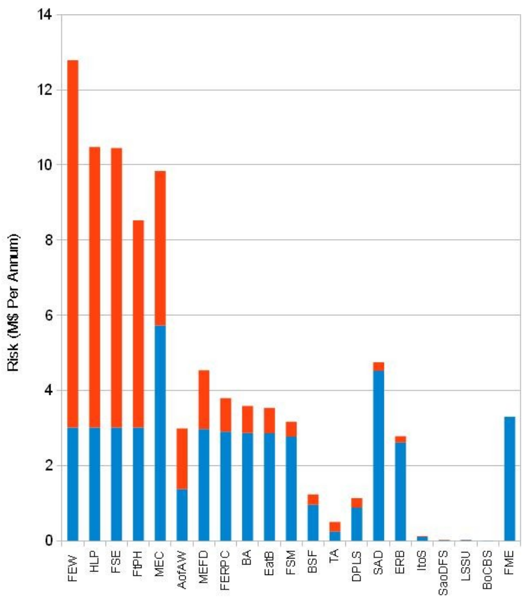


Figure 5. OT's Risk Register risks are now ranked in decreasing order (from left to right) of their intolerable part.

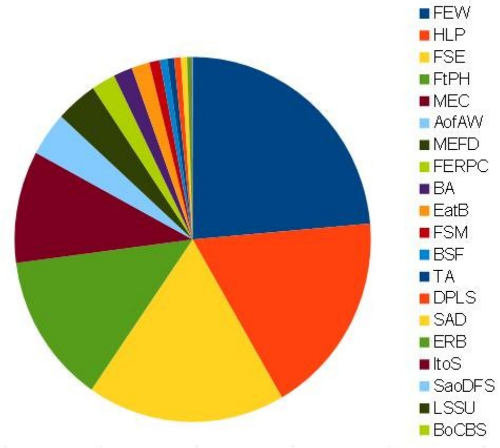


Figure 6. Relative values of the intolerable part of OT's risks.

The remaining 30 scenarios should not even be considered at this time. In other words, among the 50 risks scenario present in OT's Risk Register, 5 should be allotted 80 % of the resources and 15 others should employ 20% while the remaining 30 should not even be considered before the first 20 are not brought below the tolerability curve.

When the risk panorama will change because of implemented measures, the prioritization will change and it will be very easy to rationally and transparently update OT's ORE rankings.

### 4.4 *Summary of Results and Benefits*

From OT/AAA's original rating of 50 risks which split into 0 Severe, 14 High, 25 Medium, and 11 Low risks, by using a newly developed OT tolerability curve, and using the intolerable part of risks as a rating parameter, we determined a new rating which allows for more rational allotment of capital and effort. Following the new rating it can be seen that among those 50 risks, 5 should be allotted 80 % of the resources and 15 others should employ 20% while the remaining 30 should not even be considered before the first 20 are not brought below a tolerable level.

Comparing these values to those generated using PIGs, ORE defines 5 risks that should share 80% of the available resources, whereas PIGs finds 14 (or more?) sharing an unspecified percentage of the available resources. Or 15 risks sharing 20% of the available resources, instead than 25 sharing an unspecified percentage of the same. One other way of seeing it? Well, if Management has to mitigate 5 risks instead of 14, they will be keener to do so, and it will be done faster!

ORE benefits brought to OT can be summarized as follows:

- The prevalent critical risks were brought forward in a clear, rational and defensible way.
- The number of critical issues was shown to be smaller than originally evaluated.
- The insurance portfolio (including self-insurance policies) was shown to be poorly balanced and adjustments were proposed.
- The new priority list let Management make better mitigative investments' allotments and freed moneys that could be better allocated elsewhere in the Operation.

## 5 CASE STUDY 2

This case study bears on a complex tailings pond system, as described in Figure 7.

Each number in the Figure represents a Tailings Dam, a Spillway or a scenario. The study lead to the definition of the risk for each element (from hazards such as Stability, Erosion, Overtopping, Vandalism & Sabotage, Internal erosion, Concrete Failure, etc.). Elements are numbered 1 to 17 (Figure 7). Complex domino scenarios from multiple failure were considered.

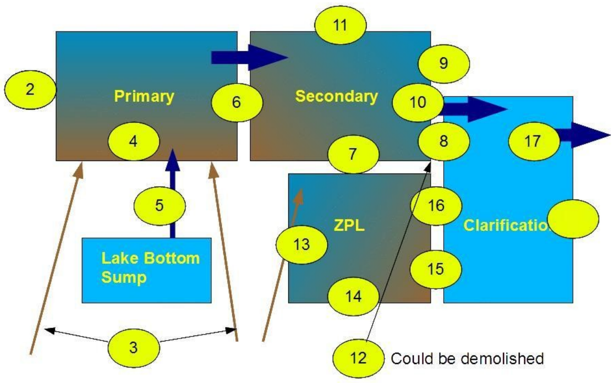


Figure 7. Tailings pond system.

As in Case Study 1, the Tolerability Curve was first developed for the client.

The intolerable bar of each element was then computed, leading to a better understanding of the risk environment as shown in Figure 9. Note that as only 6 Risks were intolerable, the remaining 13 were set aside for the short term.

If we were to proceed without ORE, *i.e*. only look at risks as displayed in Figure 8 (Total Risk per element), we would prioritize as shown in Figure 10 (Pre-ORE, Left). The same Figure 10 shows on the right the ORE prioritization.

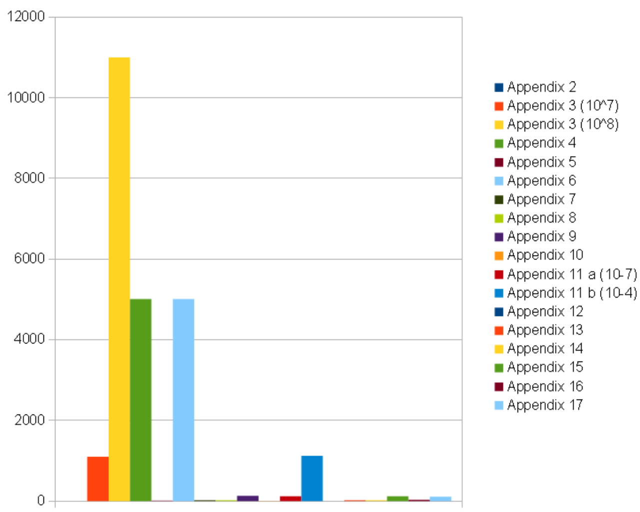


Figure 8. Total Risk per element. Each Appendix corresponds to the risk assessment of the corresponding element 1 to 17 (Figure 7).

It becomes obvious that the total risk prioritization (Pre-ORE, Left) would lead us to consider the elements described in Appendix 3,4,6 as the main drivers of the Tailings System risks, covering 88% of the total exposure.

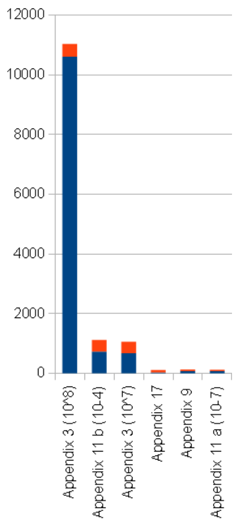


Figure 9. Intolerable Risk per element as discriminant.

Including the next three largest risks (Appendix 3 smaller scenario, 11b, 2) would lead to covering 97% of the total exposure. Again, like in other commonly used approaches, the total risk prioritization lacks definition, leads to poor allocation of funds and causes managers to be overwhelmed by the number risks that all appear to have the same level of concern.

If we focus now the attention on the ORE prioritization (Right) we see that 87% of the total intolerable exposure is shared by Appendix 3 (small and large scenario), and 11b, but 17, 9 and 11a come next (Appendix 4, 6 have vanished because their risks are tolerable). It becomes apparent now that the pre-ORE prioritization would have triggered mitigative investments toward two elements that are not critical (Appendix 4, 6).

Appendix 17 and Appendix 9 which, from a Total Risk point of view, were considered negligible, are actually intolerable and following the ORE prioritization will receive due attention.

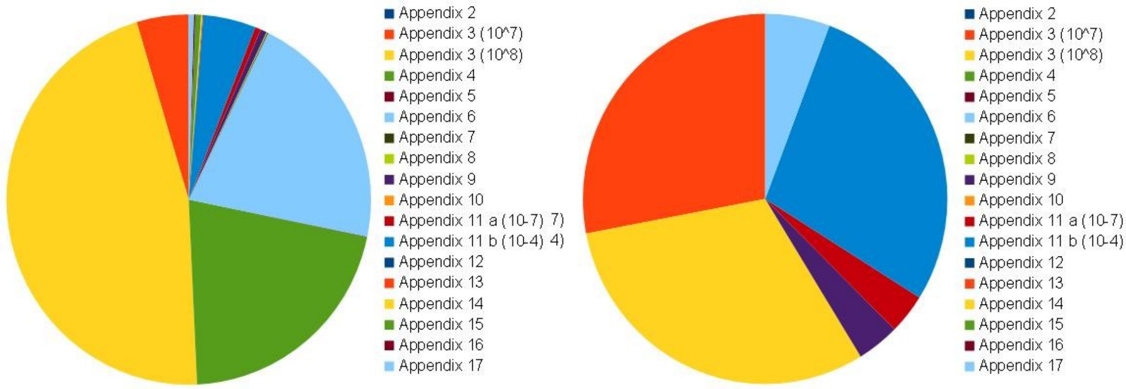


Figure 10. Pre-ORE relative Risk per element as discriminant (Left). ORE Intolerable Risk per element as discriminant (Right).

As for the elements with two different scenarios (Appendix 3,11), they were recognized as more critical than previously imagined as even their lower risk scenarios are actually intolerable.

## 6 A DEFENSIBLE APPROACH

In this section we show a summary of the replies that ORE users can give if asked to justify their doing (See http://foboni.wordpress.com/2012/03/22/avoid-liabilities-by-using-optimum-risk-estimates/ for full discussion.):

1. We did not define classes, rather we ranked risks by looking at their possible intolerable part for the specific case.
2. Probabilities were defined by methods which are applicable to available data sets, by selecting the most appropriate methodology for each scenario. Inevitable uncertainties were given due consideration ...
3. We did not need to define consequences classes.
4. We did not need to arbitrarily select “the worse” between a physical loss or human losses, or environmental losses. ...
5. We decided to use ORE because we understand the limitation and gross conceptual mistakes lined to using PIGs, and we refuse to do what everyone does as we recognize that common practice is not an excuse for negligent approaches.
6. Our tolerability criteria was established using repeatable methods specifically for the client's operation under consideration.
7. There are no cells in our ORE, no colors, and our tolerability criteria either matches well-known societal thresholds, or uses a specifically developed threshold (for physical losses) which suits client's organization needs and requirements.
8. We did not need to censor our scenarios.
9. We used a likelihood threshold of 10-5 to 10-6 for credibility, which is compliant with best practices in highly regulated industries, like, for example, chemical processing.

## 7 CONCLUSIONS

This paper shows how “standard” risk approaches, PIGs (risk assessments, risk register, ERM), can be enhanced using ORE. OREs offer a cutting-edge competitive advantage, freeing capital for business and production development, leading to more easily defensible, and justifiable decisions. In other words, the mantra is: stop wasting money and effort in mitigative measures that do not pay off, over-investing in some mitigations and probably under investing in others, with, in both cases, potentially devastating unjustified consequences. ORE prioritization is consistent, unambiguous, and provides context for better understanding organizations' risks.

ORE can be applied to projects (Project Risk Assessment), at the Pre-feasibility or Feasibility stage, or to a thriving Operation (Operational Risk Assessment), and is scalable and updatable in transparent and justifiable ways.

The benefits yielded by the approach an be summarized as follows :

- The prevalent critical risks are brought forward in a clear, rational and defensible way.
- The number of critical issues is generally shown to be smaller than originally thought.
- The insurance program is often shown to be unbalanced and adjustments can be proposed.
- The new priority list lets Management make better decisions regarding mitigative investments allotments and frees moneys that could be better allocated elsewhere in the Operation.
- The methodology allows rational updating of the probabilities when new data are gathered.

ORE can reuse most of the work already developed to establish PIGs. With ORE it is possible to upgrade existing corporate Risk Registers and to steer toward a rational, defensible and transparent stance.

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