Applying the **Total Judgement- or J_T-value** to manage oil and nuclear risks

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J-value website:
http://www.jvalue.co.uk/
NREFS Special Issue on Coping wth a Big Nuclear Accident:
https://www.sciencedirect.com/journal/process-safety-and-environmental-protection/vol/112/part/PA

- Massive, **polluting accidents** have occurred in both the **oil industry** and on **nuclear power plant**.

Oil: big accidents (selection)

- 18 March **1967**, ***Torrey Canyon*** oil tanker under charter to BP shipwrecked off the Scilly Isles. Ultimately unsuccessful **bombing raids** by RAF and Fleet Air Arm.
- 16 March **1978**, ***Amoco Cadiz*** ran aground off Brittany, 220 miles of coast polluted with crude oil. Amoco paid compensation of **$155M** 1990.
- 24 March **1989**, ***Exxon Valdez*** shipwrecked in Prince William's Sound, Alaska. 1300 miles of coast polluted with crude oil, 200 miles severly so. Final fine and compensation bill of **~$3.5bn** paid by 2009.
- 20 April **2010**, **BP Macondo** (*Deepwater Horizon*) well cap failure in the Gulf of Mexico. Uncontrolled release of crude oil for 3 months . **11 rig workers killed**, 1300 miles coated with crude oil. **$65 bn** compensation.

Notice the steeply rising costs over time

Nuclear big accidents

- 29 September **1957 Kyshtym/ Mayak** radioactive waste tank explosion, USSR. Radioactive release less than Chernobyl but of similar order.
- 10 October **1957**, **Windscale Pile 1** fire, UK. Radioactive release (orders of magnitude less than Chernobyl)
- 28 March **1979**, **Three Mile Island Unit 2** core melt. Power plant written off. Clean up cost **~$1bn**. Complete 1991 (1% of fuel still in core; safe storage conditions).
- 26 April **1986**. **Chernobyl** reactor accident, USSR. 30 workers killed. **335,000 people relocated**.
- 11 March **2011. Fukushima Daiichi** reactor accident, Japan. Caused by tsunami that itself killed >15,000 people. **111,000 relocated and 49,000 self evacuated**. $57 bn compensation, $15 bn Stage 3 decommissioning, total **$72 bn**. **Tepco cedes control** to the Japanese Government for next 13 years.

Again, steeply rising costs over time

3 key problems facing Safety Director and CEO in a Major Accident Hazard Industry

1. How do you decide **how much to spend** to protect against a bad accident happening?
2. How do you demonstrate that **enough has been spent on protection** *even when the accident subsequently happens*?
3. How can you best **mitigate** the consequences if the accident happens?

I shall be looking at the first two questions.

Ian Waddington will look at an example in the 3rd category

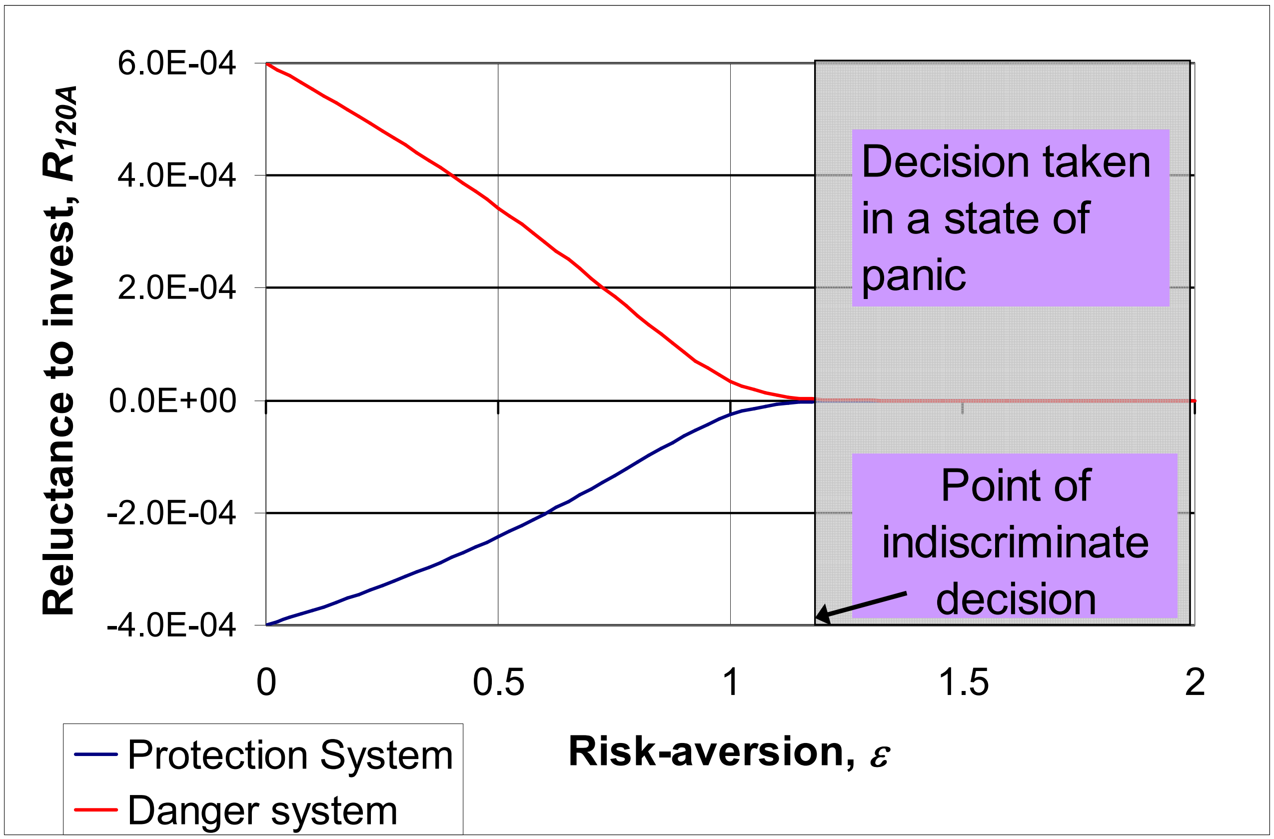
The Total Judgement or J_T-value

- The J_T-value offers an **objective, scientific** approach based on the concept of **risk-aversion**.
- A big organisation will normally make its decisions based on money, which implies a **risk-neutral** stance:
  risk-aversion = zero.
- But what about a **massive accident** like Macondo or Fukushima Daiichi?
- Wouldn't it be sensible to be **more risk-averse** when the accident, should it happen, threatens loss of control of the company?

Reluctance to invest

- Every organisation will start from a position of **reluctance to invest** in any new safety system: the spending **case needs to be made**.
- Reluctance to invest can be defined in terms of an organisation's risk-aversion: the **higher** the **risk-aversion**, the **lower** the **reluctance to invest** larger sums on protection.
- But there is an **upper limit** to how risk averse an organisation should be.
- When **risk-aversion** rises to the **point of indiscrimate decision**, the organisation can no longer distinguish amongst:
  - installing a safety system,
  - installing a danger system, or
  - doing nothing.
- This is the **organisational equivalent of panic**, when a random action can be chosen.
- Decisions **should not be taken** in a sense of **panic.**

Organisational panic explained by risk-aversion



The **point of indiscriminate decision** sets a limit for the cost of an environmental protection system

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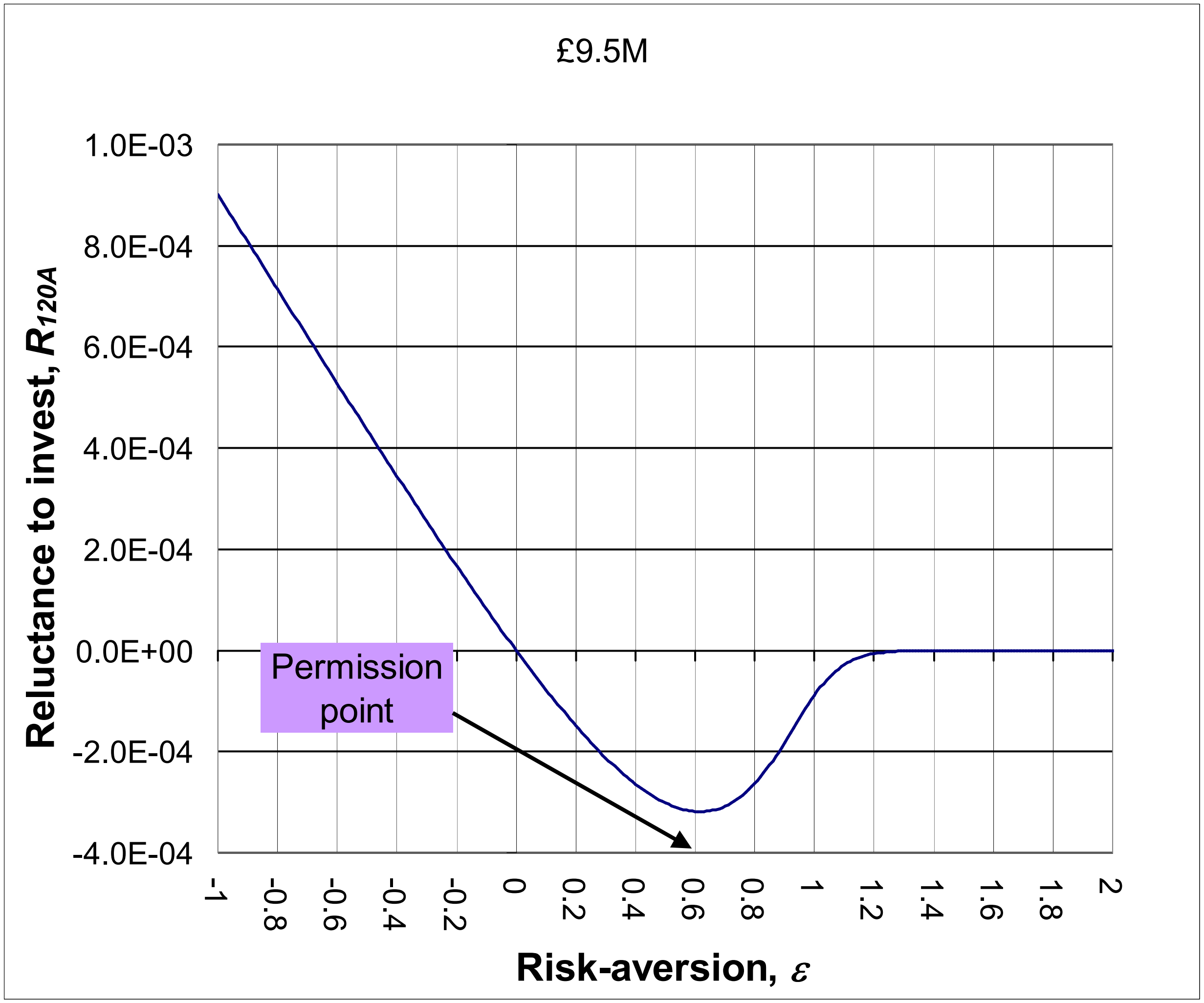
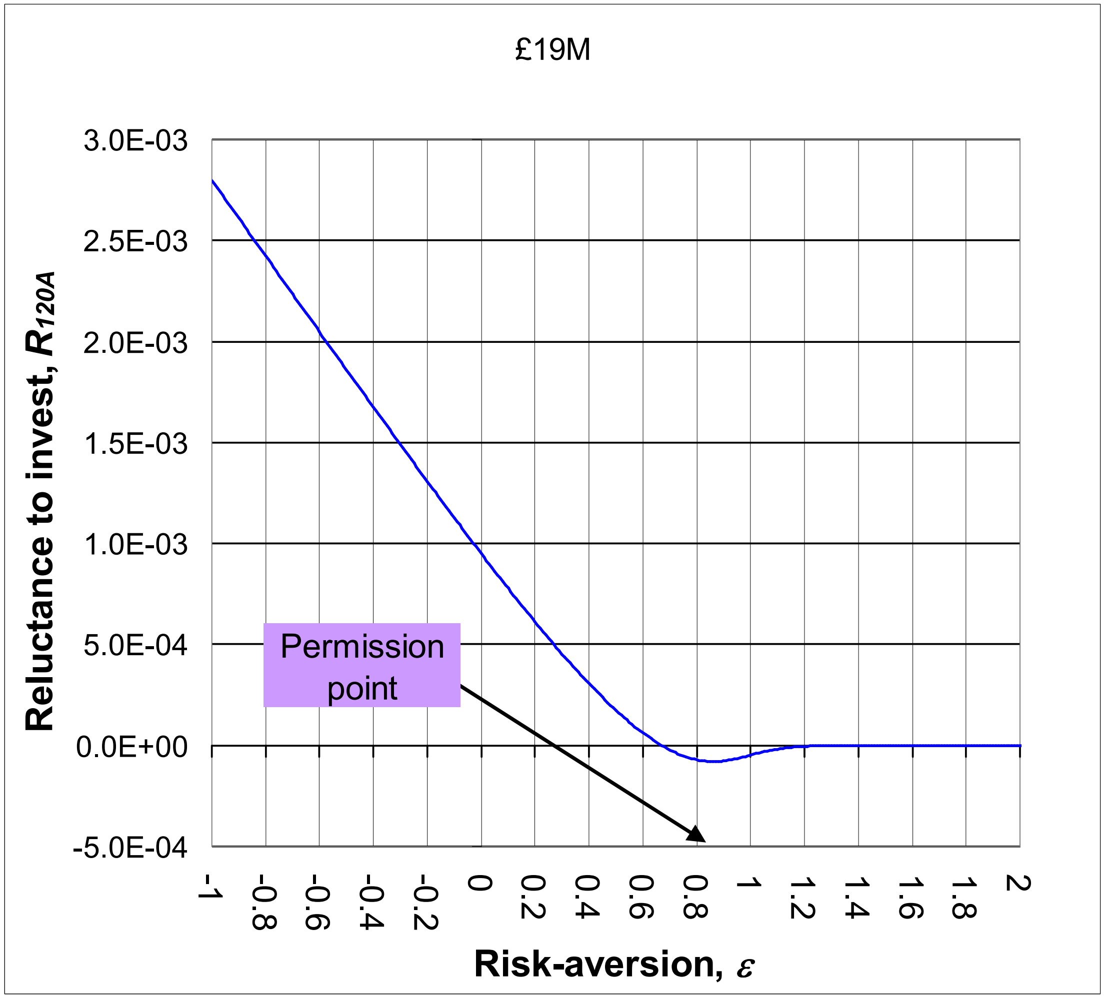
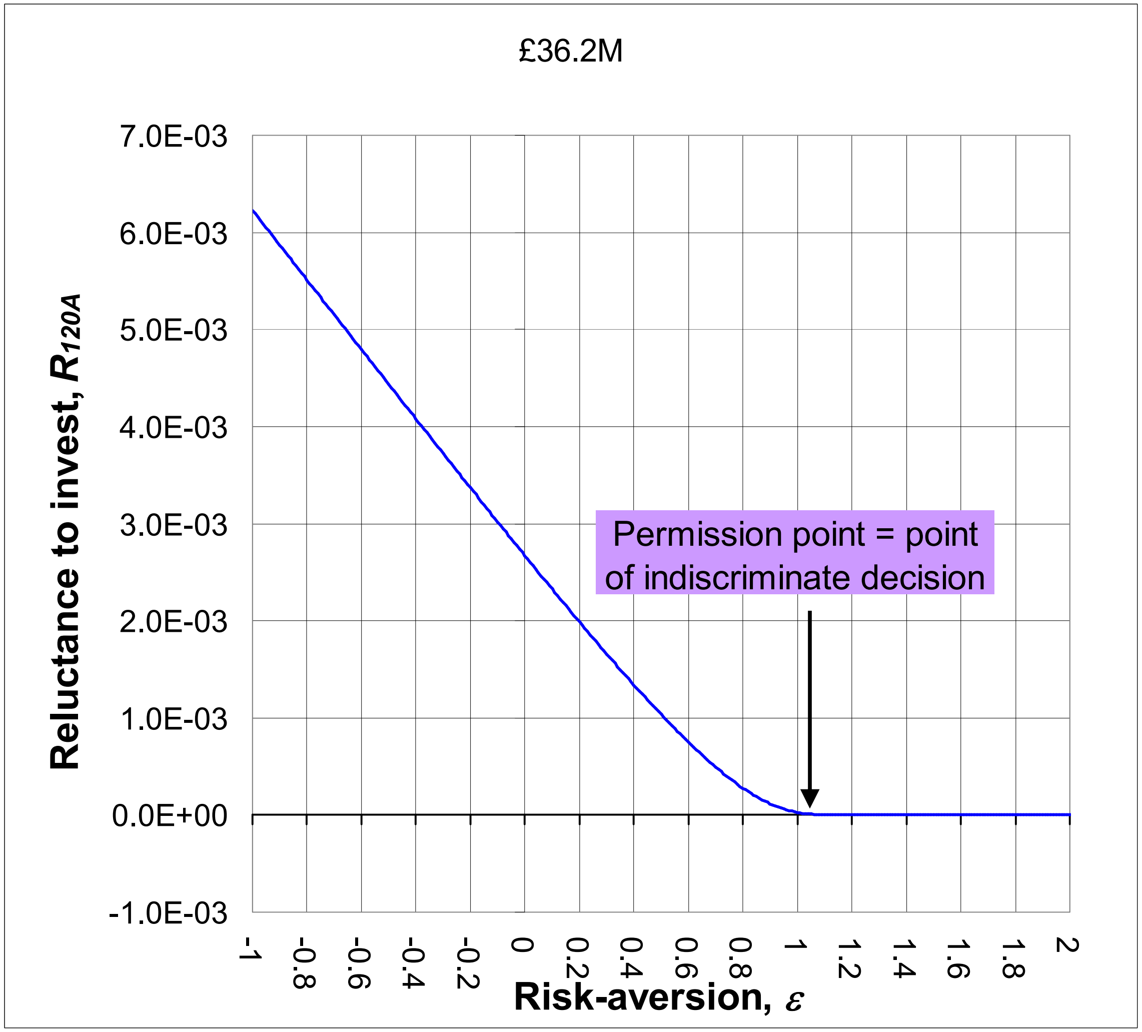
An organisation with assets of £10bn is facing a large, polluting accident with a frequency of 10^{-4} p.a. on a plant with 10 years of life remaining. The cost of the accident is £9.5 bn. How much should it pay to avoid the accident altogether?

- The growth rate of the organisation is assumed to be zero for simplicity.
- The breakeven cost (risk neutrality, risk-aversion = 0) is then approximately £9.5 x 10^{9} x 10^{-4} x 10 = £9.5 million.
- Is this the maximum the organisation should be prepared to pay?

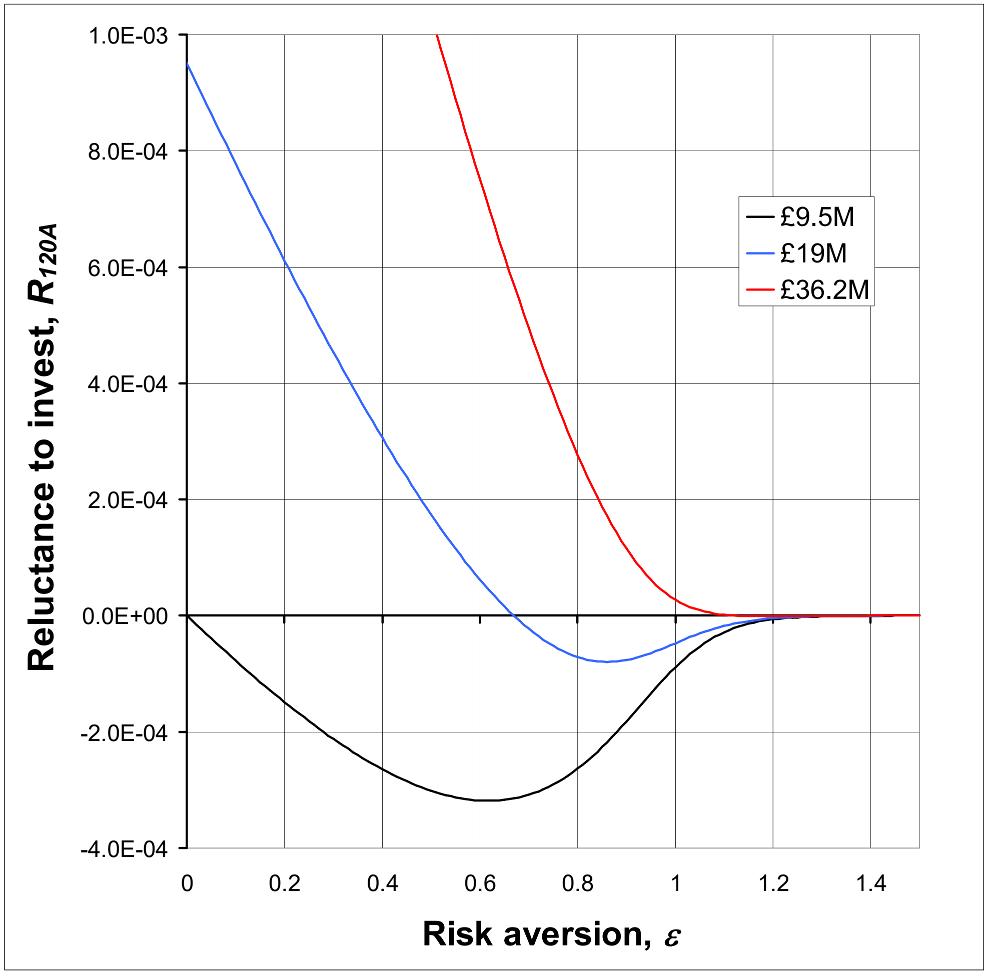


£9.5M
Reluctance to invest, R120A
1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
-2.0E-04
-4.0E-04
Permission point
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Risk-aversion, ε


£19M
3.0E-03
2.5E-03
2.0E-03
1.5E-03
1.0E-03
5.0E-04
0.0E+00
-5.0E-04
Reluctance to invest, R120A
Permission point
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Risk-aversion, ε



£36.2M
Reluctance to invest, R_{120A}
7.0E-03
6.0E-03
5.0E-03
4.0E-03
3.0E-03
2.0E-03
1.0E-03
0.0E+00
-1.0E-03
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Risk-aversion, ε
Permission point = point of indiscriminate decision


1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
-2.0E-04
-4.0E-04
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Reluctance to invest, R_{120A}
Risk aversion, ε
£9.5M
£19M
£36.2M

BP Macondo oil well, Deepwater Horizon explosion and oil release, 20 April 2010.

- 11 people killed, 17 injured.
- Compensation: $65 bn. Maximum drop in BP capitalisation: $180.8bn on 29 March 2010 to $91.91bn on 28 June 2010, a drop of ~$90bn. Take this as the cost of the accident to BP.
- Market cap recovered to average about $130bn for the two years or so after well capping on 15 July 2010, down about $50 bn from $180.8bn.
- BP market cap had been rising in the decade to 2006, but was declining to 2010, from $257.7bn on 1 May 2006 to $180.8bn on 29 March 2010. Assume a 0.0% growth rate in first instance.
- Assume drilling rig has an operational lifetime of 10 further years.
- Assume that the frequency of such a large accident occurring was 10^{-4} per year but that additional protection could reduce this to 10^{-6} per year at a cost of $100 million. Would this be worth it?

J_T-value calculation: parameters

Starting wealth (USD)	180.8 bn
Growth rate (% p.a)	0.0
Cost of accident (USD)	90.0 bn
Lives at risk	20
Duration of protection	10 years
Starting frequency (p.a.)	10^{-4}
Frequency post protection	10^{-6}
Cost of protection (USD)	100.0 M

Human life: J-value

- Assume that BP's rig workers were British.
- UK **GDP per head** in 2010 was **36,363 USD**.
- Life expectancy of the average male worker in the UK in 2010 was **40.09** years. **20 workers** faced losing this expected amount of life.
- Expected loss of life per worker without the new protection measures = $10^{-4}y^{-1}$ x 10y x 40.09 = ~4.1 x 10^{-2} y – about **15 days**
- Expected loss of life per worker with the new protection measures = $10^{-6}y^{-1}$ x 10y x 40.09 = ~4.1 x 10^{-4} y. Expected loss of life averted = ~3.97 x 10^{-2} y for each of 20 workers – about **4 hours each**.
- A maximum of **$320,000** can be calculated using the **J-value** as being justifiable for the protection system based on its role in extending human life (J = 1.0).
- The actual cost, £100M, so that the J-value would have been 100 x 10^6 / 3.2 x 10^5 = **312**, far higher than the **justifiable J-value of 1.0**.

Including the environmental costs of $90 bn

- When the organisation's growth rate is 0% p.a., the expected loss without protection is 90×10^9 \$ $\times 10^{-4}$ $y^{-1} \times 10$ y = \$90,000,000. With protection, the expected loss is 90×10^9 \$ $\times 10^{-6}$ $y^{-1} \times 10$ y = \$900,000
- Expected loss averted is the difference: **$89,100,000**.
- Add on the justifiable amount for extending human life and the total is **$89.42 M**. This is less than the cost of the protection system, which is **$100 M**.
- So the protection system would **not** be justified **based on a risk-aversion of zero**, where only the money matters.

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But it is reasonable for companies to be be more risk averse when facing losing control of the organisation? This is the situation modelled using the J_T-value framework

- The significant loss, roughly half the capitalisation, means that the **risk-aversion** at which the decision should be taken rises from 0.0 to **0.98**, and this induces a Risk Multiplier of **1.335**.
- The justifiable spend on protection rises to 1.335 x $89.1 M = $118.98 M. Adding on the J-value justified pure safety spend gives **$119.3 M**.

The J_T-value

- J_T = actual spend/(justifiable spend to protect the environment and humans)

  = \$100M/\$119.3M

  = 0.84.
- Since $J_T <= 1.0$, the Board **would have been justified** in sanctioning \$100M on the protection system.
- Any sum up to **\$119M** would have been reasonable.
- Importantly, such expenditure, carried out to a proper professional standard, would have been **fully defensible in court**.

Comments on the BP Macondo example

- The calculations are purely **illustrative** for the sort of accident that might have occurred on an oil rig drilling in the Gulf of Mexico.
- The posterior probability of the accident was clearly 1.0 - it happened! And there is **no guarantee** that a reasonable prior probability was 10^{-4} p.a.
- The **$90 bn** figure used as the cost of the accident is obviously above the eventual **$65 bn** compensation cost.
- Only a very large company would be able to incur a costs of this order and continue trading.
- Moreover, the company board might have thought that a drop in capitilization of **$100 bn** might have been possible. This could well have led to loss of control of the company through takeover.
- A prospective loss of **$100bn** would roughly **double the Risk Multiplier** for BP.

Conclusions

- The new J_T-value method allows **fully rational and non-subjective decisions** to be taken on **how much** an organisation should spend on **protecting human life and the environment**.
- **Decisions** backed by the **new quantitative methods** provide **positions that can be defended in court.**

References

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