A BRIEF HISTORY OF RISK ASSESSMENTS

by P J N Pells

1. THE ORIGINS

For hundreds of thousands of years, us *homo sapiens* have sought explanations for the unpredictable and inexplicable events that impact on our lives, whether weather, or pestilence or crop failures or failure hunting animals. We have ascribed such events to gods we have invented , or evil spirits, or to karma ,or to luck.

Starting about 2000 years ago some clever *homo sapiens,* like Archimedes and Euclid and Pythagoras and the Chinese authors of *Zhou Bi Suan Jing* started demonstrating that certain events or outcomes could be determined by mathematics, particularly geometry. This process of determining the behaviour of certain physical processes and removing them from the realm of magic and the gods, came to its first peak in the works of people like Newton, Descartes and Mendel. But these deterministic methods could not deal with uncertain outcomes as in games of chance, and despite all their other achievements in mathematics, the Chinese and Mesopotamians and Greeks failed to deal with this issue.

It is agreed amongst scholars, who know these things, that it was in letter correspondence between Blaise Pascal (died 1662 at age 39) and Pierre de Fermat (died 1665 at age 64), in relation to a particular game called Points, that saw the first proper calculation of probability.

The correspondence occurred in between 1654 and 1660 (Pascal then 37 and already ill) and included calculation of probable outcomes if a game was terminated early and the players wished to divide the pot equitably. We don't need to go into the details of their methods here. The important point is that they calculated the probability of different outcomes and thereby could set out equitable consequences.

2   PASCALS WAGER

It is suggested that Pascal wrote down the arguments of his wager between 1657 and 1658 (incorporated in the book *Pensees*). The argument goes on for three pages of dense text, but the essence is in the following quote:

> Yes, but a bet must be laid. There is no option: you have joined the game. Which will you choose, then? Since a choice has to be made, let us see which is of least moment to you. You have two things to lose, the true and the good; and two things to wager, your reason and your will, your knowledge and your happiness; and your nature has two things to shun, error and unhappiness. Your reason suffers no more violence in choosing one rather than another, since you must of necessity make a choice. That is one point cleared up. But what about your happiness? Let us weigh the gain and the loss involved in wagering that God exists. Let us estimate these two probabilities; it you win, you win all; if you lose, you lose nothing. Wager then, without hesitation, that He does exist.

Again, as with the game of Points discussed above, Pascal is considering probability, in this case Yes, or No, and the consequence. Nothing is gleaned from probability consideration, and it is all about the consequences.

3   PORT ROYALE and the book LOGIC, OR, THE ART OF THINKING

Port Royale was an Abbey in Paris and was the centre for learning and debate. The Abbess was Angelique Arnauld, daughter of a prominent Lawyer and one of 10 children who survived childhood. One of her brothers was Antoine Arnauld who was part of a community of laymen (the *solitaires*) who lived in the environs of the convent. They published numerous religious and philosophic works. One of their frequent visitors was Blaise Pascal, whose sister was in the Abbey, and who made a large financial donation to the Abby.

In 1662 Antoine Arnauld and Pierre Nicol published a book titled, in English, "*Logic, or, The Art of Thinking*".

There is little doubt that portions of this book owe their origins to Pascal, and some portions may have been written by him. It is known that the book had its origins in separate documents, and it is clear that the style in places represents Pascal. But we cannot know if Arnauld learned from Pascal or *visa versa*.

In terms of Probability, Consequence and Risk, the key part is in the last two pages of the book, where we find the following:
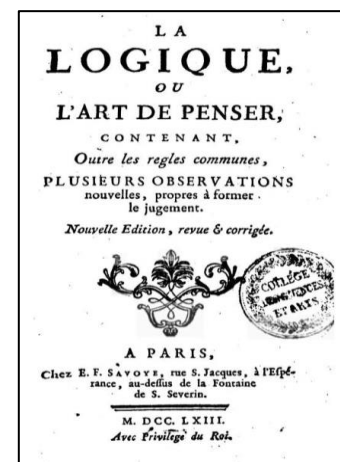
> *But with respect to accidents in which we play a part, and that we can bring about or prevent in some sense by our care in exposing ourselves to them or avoiding them, many people happen to fall into an illusion that is all the more deceptive as it appears more reasonable to them.*

> *This is that they consider only the greatness and importance of the benefit they desire or the disadvantage they fear, without considering in any way the likelihood or probability that this benefit or disadvantage will or will not come about.*

There is other interesting material, including:

> *So, then our fear of some harm ought to be proportional not only to the magnitude of the harm, but also the probability of the event.*

This is the heart of Risk Assessment as practiced in the 21st Century.

4.   DANIEL BERNOULLI

80 years after the writings of the Port Royale, Daniel Bernoulli published a book, titled in English, "*Exposition of a New Theory on the Measurement of Risk*". In that book he introduces the idea of the **utility** of a gain. His point is that the utility of a gain or loss will be different for different people, even though the amount is the same. He says, "it seems clear that all men cannot use the same rule to evaluate the gamble".

Despite that Risk Assessment is often ascribed to Bernoulli, this is false.

As explained by Kaplan and Garrick (1981), Risk Assessment, as defined by Pascal and now used internationally, answers three questions:

Q1: *What can go wrong?*

Q2: *How likely is it to go wrong?* (**Probability** also called **Likelihood),** and

Q3: *If it goes wrong, what is the outcome?* (**Consequence**)

However, they point out that in Decision Making there is a 4th question:

Q4 *"How do you (the decision maker) feel about the result"? In other words: "how much does the decision maker want to avoid the outcomes representing loss.*

This 4th question is what Bernoulli addressed.

5.   QUALITATIVE RISK MATRIX

It is interesting that it was 322 years after Pascal explained Risk, that the first <u>qualitative</u> risk matrix was produced by the United Department of Defence and published in 1984[1]. This was soon picked up by other major organisations such as Halliburton[2].

It seems to me that there is a fine line between the 1984 qualitative risk matrix and the quantitative definition of risk given 3 years earlier by Kaplan and Garrick[3], but this just makes the gap 319 years since Pascal's work.

A copy of the 1984 U S Dept. of Defence Risk Matrix is given below.

FIGURE 1.   FIRST EXAMPLE HAZARD RISK ASSESSMENT MATRIX

FREQUENCY OF OCCURRENCE	HAZARD CATEGORIES			
	I CATASTROPHIC	II CRITICAL	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENT	1A	2A	3A	4A
(B) PROBABLE	1B	2B	3R	4B
(C) OCCASIONAL .	1C	2C	3C	4C
(D) REMOTE	1D	2D	3D	4D
(E) IMPROBABLE	1E	2E	3E	4E

Hazard Risk Index	Suggested Criteria
1A, 1B, 1C, 2A, 2B, 3A	Unacceptable
1D, 2C, 2D, 3B, 3C	Undesirable (MA decision required)
1E, 2E, 3D, 3E, 4A, 4B	Acceptable with review by MA
4C, 4D, 4E	Acceptable without review

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[1]ÚS Dept of Defence MIL-STD-882B System Safety Program Requirements https://mail.system-safety.org/Documents/MIL-STD-882B.pdf

[2]

[3] Kaplan S and Garrick B J (1981) *On The Quantitative Definition of Risk.* Risk Analysis Vol 1 No 1.

The Forword to the 1984 document includes the following important statement:

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The success of the system safety effort depends on definitive statements of
safety objectives and requirements by the managing activity and their
translation into functional hardware and software.  A formal safety program
that stresses early hazard identification and elimination or reduction of
associated risk to a level acceptable to the managing activity is the
principal contribution of effective system safety.  Selective application and
the tailoring of this military standard must be accomplished, as indicated
herein, to specify the extent of contractual and DoD in-house compliance.
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The 1992 Halliburton commences with the following:

Introduction

"Is the risk acceptable?"—a simple question which has no simple answer. Chemical manufacturing designers, manufacturers, and handlers regularly make evaluations and judgements regarding the acceptability of a given specific risk in a given specific set of circumstances. The spoken question is "Is this operation condition safe?" Yet the *actual* question is "Is this operational condition *safe enough?*"

The answer to this Halliburton question is the same as the answer to Q4 in Section 4, above. The answer resides with the Decision Maker based on "**utility**" as set out by Daniel Bernoulli in 1722.