CHEMICAL ENGINEERING TRANSACTIONS
VOL. 77, 2019
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Genserik Reniers, Bruno Fabiano

ISBN 978-88-95608-74-7; **ISSN** 2283-9216
DOI: 10.3303/CET1977142

Unknown Risk: The Safety Engineer's Best and Final Offer?

Paul Lindhout

Delft University of Technology, TPM Safety & Security Science Group, Jaffalaan 55, Delft, The Netherlands.
P.Lindhout@TUDelft.nl

A significant gap exists between accident scenarios as foreseen by company safety management systems and actual scenarios observed in major accidents. Its mere existence, pointing at flawed risk assessments, is leaving hazards unmitigated, threatening worker safety, putting the environment at risk and endangering company continuity. Safety managers and regulators, attempting to reduce and eventually close this gap, not only encounter the pitfalls of poor safety studies, but also the acceptance of "unknown risk" as a phenomenon, companies being numbed by inadequate process safety indicators, unsettled debates between paradigms on improving process safety, and inflexible recording systems in a dynamic industrial environment. The immediacy of the stagnating long term downward major accident rate trend in the Netherlands underlines the need to address these pitfalls. The main conclusion is that safety management can never be ready with hazard identification and risk assessment.
Keywords: Unknown risk, Seveso Directive, scenario, accident rate, HRO

1. Introduction

What lies beyond the border between known and unknown parts of the world around us is not merely a remote mystery. It affects us all in everyday life. Although causes of frequent occupational accidents are usually rather well understood and countermeasures can be taken, this is not so in companies where complex processes and installations are running to store, mix and produce hazardous chemical substances (Galen & Bellamy, 2015). There, right in front of our eyes, the mystery shows itself through observed events during major accidents which do not consistently match with foreseen accident scenarios (Kleindorfer et al., 2003). This 'scenario gap' shows between the risks that actually exist and the risks that are being managed. The mere existence of this gap points at risk management which is apparently failing also on other aspects (Hubbard, 2009). The gap is significant since major accidents pose a near to constant level of threat to society in the Netherlands and Belgium over the past 35 years (Swuste & Reniers, 2017). It indicates that major accident prevention falls short and that further improvement of risk control is necessary (Le Coze, 2013).

2. Problem definition

Firstly, risk assessments can be incomplete or incorrect for many reasons, like the focus on unlikely worst case scenarios (Kleindorfer et al., 2003), wrong indicators (Kingston & Dien, 2017), lack of 'risk appetite' (Gjerdrum & Peter, 2011), and looking at single failures only rather than at multiple factor causation (Edwards et al., 2012).

Secondly, experts might acknowledge a scenario and do nothing about it but for accepting it as residual risk for economic reasons (Ale & Mertens, 2012).

Thirdly there can be unknown risk (Lindhout & Reniers, 2017), of which one can either be aware, hence known-unknown risk, or unaware, hence unknown-unknown ('unk-unk') risk (Ramasesh & Browning, 2014).

Arguably the fourth pitfall is the claim that some risks are not foreseeable (Galen & Bellamy, 2015), e.g. due to the sheer number of possibly harmful combinations of conditions or events, their interdependency or interaction and their uncertainties.

Obviously any unidentified risk resulting from either of these pitfalls is at the same time an uncontrolled risk. Such a risk jeopardises effective accident prevention and threatens worker safety, it puts the environment in harms way and endangers company continuity. This paper deals with the question:

Paper Received: 30 October 2018; Revised: 31 May 2019; Accepted: 12 July 2019

Please cite this article as: Lindhout P., 2019, Unknown risk: The safety engineer's best and final offer?, Chemical Engineering Transactions, 77, 847-852 DOI:10.3303/CET1977142

What can the safety engineer do about unknown risks in the chemical industry?

3. Method

A four steps approach is used:
1-Literature is explored on paradigms on how to handle unknown risks.
2-Based on phenomena and their place in the existence field, an unknown-ness scale is established.
3-A method, using this scale, for assessing an inventory of ‘known-unknown’ risks as derived from lived experiences in the chemical industry, is proposed.
4-Finally, in a discussion section, a way forward is presented for the safety engineer, towards more complete risk assessments.

4. Results

4.1 How to handle unknown risks?

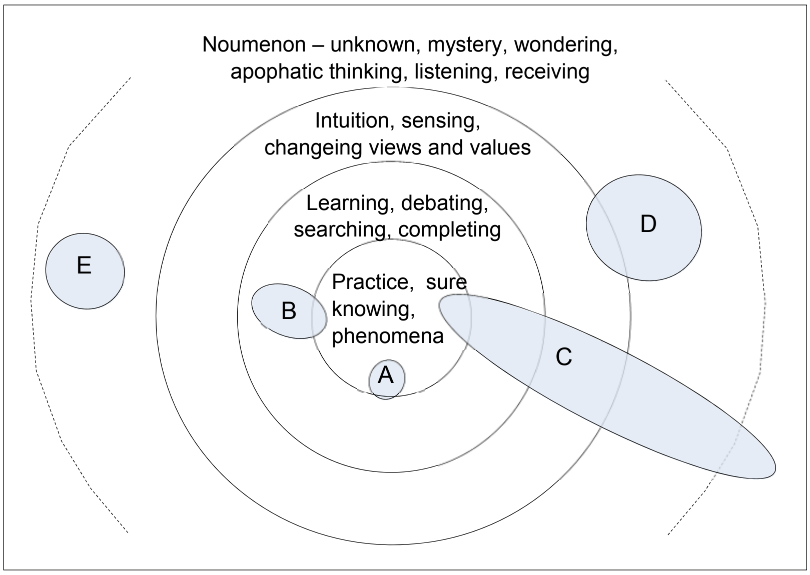
Accidents are a sequence of events leading to the release of energy or toxicity in an unwanted and uncontrolled way, usually referred to as a scenario. In a complex chemical process plant many accident scenarios are possible.
The EPSC (European Process Safety Centre) places such a scenario in a matrix of awareness versus knowledge, each being either known or unknown. In the resulting square the unknown may be at the awareness side, then requiring constant attention and keeping a sense of vulnerability. It may also be at the knowledge side, then requiring study. When both sides of a scenario are unknown, everything is needed, together with creativity and a pro-active approach around the question “what else?” (Gowland, 2011). Clearly this is not a vote for accepting unknown risk as a fact of life, nor for accepting it as a phenomenon which we would not be able to do anything about.
So, how to go about this? Extrapolating the past and an evidence-only approach (Pawson et al, 2011) seems not enough to foresee what’s next. Can we learn enough from accidents and near misses even if we capture all there is to learn? Can we still rely on fixed accident causality recording methods while the pace, in which new technology, insights and methods emerge, indicates that we are entering a fourth industrial revolution (Schwab, 2017)?
Here unsettled debates between paradigms are overwhelming the safety engineer with many questions. Is what safety specialists do about it sensible and logical? Is meticulously following the ISO-31000 risk management standard, prescribing the identification of *all risks*, really the best we can do? Is our mental model requiring a major overhaul towards ‘total respect’ (Blokland & Reniers, 2017)? Might it be the anticipatory thinking (Klein et al., 2007) we need to embrace? Is it possible to avoid problems by more emphasis on safety during the design phase (Husin et al, 2017)? Could installations even be made completely inherently safe (Ahmad et al., 2017)? Or can we just cover any uncontrolled risk with resilience engineering (Haavik et al., 2016)? Are risk assessments getting better with ‘Safety-II’ in mind (Hollnagel et al., 2014)? Would it be possible to rule out human error in situations requiring fast and smart response to unforeseen danger (Bellamy, 2018)? Is it wise to embark on integrated design-based safety and security or on a collaborative approach between competitors (Reniers & Amyotte, 2012)? Should we use more artificial intelligence and sensor technology as a ‘nervous system’ monitoring scenario safety state in chemical plants (Uraikul et al., 2007)? Is it all merely a matter of perception (Slovic & Weber, 2002)? Is it simply a matter of ‘safety-intelligence’, in other words providing a constant stream of information about error producing conditions to educate the top executive level (Kirwan, 2008)? Should we -first of all- reconsider the way the regulator operates as it is creating its own disasters (Black, 2014)? Must we keep hunting for black swans (Taleb, 2007)? How would we know if our search for dangers is done anyway (Cantrell & Clemens, 2009)? Could we ever be ready since there seems to be an ‘unknowable’ realm we can never get to (Pawson et al., 2011)?

4.2 Phenomena and existence field

It comes as no surprise that Taylor-Gooby & Zinn (2006) conclude that risk research suffers from a wide range of perspectives. It would seem that the drops in industrial accident rates since the nineteen fifties following the successive introductions of safety technology, safety management and safety culture have come to a plateau (Hudson, 2007).
So, are safety specialists at their whit’s end here? Confronted with all these thinking directions, safety science seems to be ‘dead in the water’, indecisive, not knowing what direction to go. Philosophy may offer a proverbial ‘tow-boat’ here.
Already the earliest scientific thinking about the world, as we experience it around us, included a notion that there could be more than we are aware of. Something that the Greek philosophers would consider as a known

part of physical reality, appearing from direct observation via the senses, was labelled a ‘phenomenon’. Any remaining, assumed to be existing but as yet undiscovered part of reality was referred to as ‘noumenon’. Science in general and phenomenology in particular, is geared to discover and understand phenomena coming from this mysterious realm (Merleau-Ponty, 1945). Although some phenomena may not immediately appear (Heidegger, 1927), and much of the phenomenologists’ effort is focused on investigating subjective lived experience in people’s lives, rather than facts in the physical world, the basic question in phenomenology: “How does the world appear to human consciousness?” (Husserl, 1969) might be helpful to explore undiscovered things in safety science. This differs from the stance taken by the scientists in physics, when they empirically explore ‘the real world’ beyond what is currently detectable with human senses and their extensions in the form of technical equipment (Humphreys, 2004). But how to reach for the unknown of which we are ignorant?

In line with current philosophical thinking, reality can be mapped with any known phenomenon in the centre, transitionally less known concentric domains around it, and a completely unknown, ‘noumenon’ domain at its outskirts (Hansen, 2018) as shown in figure 1. A complete ‘saturated’ phenomenon can consist of parts scattered over the different domains in this existence field (Marion, 2002). Some part of such a phenomenon is known, some of it is not fully known, some of it is not known though knowable, some of it is not known at all. In each of these domains a different strategy is required to learn about what is going on there and move in the direction from the unknown outer rim towards the sure-known area in the centre. The centre represents the every day world where cognition and practice rule, where empirical science can build evidence. The first domain around the centre is an area dominated by ontology, where we need suspiciousness, wondering, learning, debating, and finding new words to describe things not seen before. The next domain, another step further from the centre, is the realm of intuition, coincidental discovery and changing our values and views on the world. Even further ‘out there’, is the unknown domain where mystery and wonder rule (Hansen, 2018). This dark and mysterious realm requires apophatic thinking and keeping an open mind, looking for what is not said and what is hidden in between the lines (Arendt, 1978). Postulating an even more distant domain in order to make the distinction between knowable and unknowable has little practical meaning since the latter could neither be known nor dealt with (Ramasesh & Browning, 2014). In figure 1 this distinction is indicated with a dashed outer perimeter.



A - Thermal expansion, most of it being well understood
B - Risk taking behaviour, observed but not yet fully understood
C - The big-bang which might partly remain unknowable to mankind
D - Unidentified accident cause waiting to be revealed
E - Unknown danger, not yet recognized as a phenomenon

Figure 1 Reality in four realms with example phenomena. (Simplified from: Hansen, 2018)

4.3 Risk unknown-ness scale

Preparing for the unexpected requires things like attention for weak signals, embracing failure in its full depth and detail and – preferably – having hands-on knowledge of the plant to really understand what is going on (Weick & Sutcliffe, 2007). For this study a generally applicable scale indicating ‘unknown-ness’ is needed. In order to look at movement in the continuous flow associated with increasing awareness, moving from unknown to known, at least some stepping stones between the two extremes, known (phenomena) and unknown (noumena), would come in handy. Peirce (1867), the founder of “pragmatism”, used a simple three stages approach for this and coined them Firstness, Secondness and Thirdness. Firstness is about a

condition, existence, possibility, not yet thought about, understood or described. Secondness is about emerging relations between facts and observable things, exposing differences, objects and interactions. Thirdness is about recognizing patterns, allowing naming, connecting, grouping, classification, arranging, explaining, predicting and anticipating, in other words: something almost getting known to the extent needed to identify it as a phenomenon.
Peirce's (1867) three stages between known-unknowns and unknown-unknowns compare rather well to the domains in the existence field map, reflecting current mainstream philosophical thinking (Hansen, 2018), as is shown in table 1.

Table 1: Risk unknown-ness scale and action approach

Unknown-ness Scale level	1 Known Phenomenon	2 Thirdness	3 Secondness	4 Firstness	5 Unknown Noumenon
Stages attributes Peirce (1867)		Recognizing patterns, allowing naming, connecting, grouping, classification, arranging, explaining, predicting and anticipating	Relations between facts and observable things, exposing differences, objects and interactions	Condition, existence, possibility, not yet thought about, understood or described	
Reality map attributes Hansen (2018)	Cognitive, every day, facts, empirical evidence, sure known	Ontology, learning, debating, new terms, new things	Intuition, coincidental finds, changing values and views	Known-unknowns Passive listening, Apophatic thinking, open mind	'Unknown-unknowns', wondering, mystery
Proposed action approach	Reduce and / or control these risks	Investigate these risks, bring them to phenomenon level and plan to bring them under control	Study these risks by observing & recording finds, change thinking on views and values, gathering information to bring them to Thirdness level	Use intuition, be curious, be creative	

4.4 Known-unknown risks inventory

Lindhout & Reniers (2017) present an inventory of known-unknown uncontrolled risks as derived from regulator experience in the Dutch chemical industry. This example inventory, suitable as a starting point for any safety engineer in any company, shows a spread over the unknown-ness scale so that different appropriate actions can be taken as proposed in table 1.

5. Discussion

Having these known-unknown uncontrolled risk types identified and actions defined, what can safety engineers do more? The first thing would be to adapt their own thinking about acceptability of unknown risks and their views on the prevention of major accidents. Simply not stop wondering about the dark mystery staring them in the face every day, and keep looking for new horizons and new scenarios. This approach can be used as a tool to systematically reduce the unknown-ness in the known unknown and uncontrolled, risk inventory, adding measures as necessary. Hence the safety engineer is thereby able to continuously improve safety rather than remain at a standstill, when settling for ‘unknown risk’ as a fact of life.

6. Conclusion

The immediacy of the stagnating long term downward major accident rate trend in the Netherlands underlines the need to address any uncontrolled risks, including the known unknown risks. The first conclusion is that there is a way to systematically increase knowledge on known-unknown risks.

The second conclusion is that safety management can never be ready with hazard identification and risk assessment since there is a continuous flow of unknown dangers from the outer perimeter of reality towards the sure-known center.

Finally, no risk assessment will ever be complete. Philosophers contend that there is more ‘out there’ than we can possibly imagine . . .

Acknowledgement

The author thanks dr. John Kingston-Howlett, prof. dr. Finn Thorbjørn Hansen and prof. dr. Genserik Reniers for their critical, valuable and inspiring comments.

References

Ahmad S.I., Hashim H., Hassim M.H., 2017, Inherent Safety Assessment Technique for Preliminary Design Stage. Chemical Engineering Transactions, Vol 56, 2017, p 1345-1350.

Ale B.J.M., Mertens F.J.H., 2012, Toezicht op ondernemingen in de chemische industrie. The Netherlands, Den Haag: WRR. Webpublicatie nr. 66, p 59.

Arendt H., 1978, Life of the Mind. USA, New York: Harcourt Brace Jovanovich.

Bellamy L.J., 2018, Doing What Is Right or Doing What Is Safe. An Examination of the Relationship between Professionalization and Safety. In: Bieder C. et al. (eds.), Beyond Safety Training, Safety Management, Chapter 9. Doi 10.1007/978-3-319-65527-7_9.

Black J., 2014, Learning from Regulatory Disasters. LSE Law, Society and Economy Working Papers 24/2014. UK, London.

Blokland P., Reniers G., 2017, Safety and Performance. Total Respect Management (TR^3M) A Novel approach to Achieve Safety and Performance Proactively in Any Organisation. USA, New York: Nova Publishers.

Cantrell S., Clemens P., 2009, Finding All the Hazards How Do We Know We Are Done? Professional Safety, Vol. 54, Issue 11.

Edwards T., Sharples S., Wilson J.R., Kirwan B., 2012, Factor interaction influences on human performance in air traffic control: The need for a multifactorial model. Work, Vol. 41 (2012), p 159-166.

Galen A. van, Bellamy L.J., 2015, Dealing with uncertainty in practice strengths and traps in human intervention. In: Succes in the face of uncertainty, final report, resiliencesuccessconsortium.com [accessed May 26, 2018].

Gjerdrum D., Peter M., 2011, The New International Standard on the Practice of Risk Management. A Comparison of ISO 31000:2009 and the COSO ERM Framework. Risk Management, March 2011, Issue 21, p 8-12.

Gowland R., 2011, Lessons learned after disasters in the Chemical Industry. epsc.org [accessed May 26, 2018].

Haavik T.K., Antonsen S., Rosness R., Hale A., 2016, HRO and RE: A pragmatic perspective. Safety Science, online 23 August 2016. doi.org/10.1016/j.ssci.2016.08.010.

Hansen F.T., 2018, At møde verden med undren: Dannelse, innovation og organisatorisk udvikling i et værensfilosofisk perspektiv. [English: To Meet the World in Wonder: Education, Innovation and Organisational Development in an Existence Philosophical Perspective]. Danmark, Copenhagen: Hans Reitzel.

Heidegger, M., 1927, Sein und Zeit. 7th ed, Neomarius Verlag, Tübingen. (Being and time: English translation by John Macquarrie & Edward Robinson, 1962, Harper & Row from: Sein und Zeit,) p245-246. USA, New York: SUNY press, 1996.

Hollnagel E., 2014, Safety-I and Safety-II. The past and Future of Safety Management. UK, Farnham, Surrey: Ashgate Publishing Ltd.

Hubbard D.W., 2009, The Failure of Risk Management. USA, Hoboken, NJ: John Wiley & Sons Inc.

Hudson P., 2007, Implementing a safety culture in a major multi-national. Safety Science, Vol 45, Issue 6, p 697–722.

Humphreys P., 2004, Extending ourselves: Computational science, empiricism, and scientific method. UK: Oxford University Press.
Husin M.F., Hassim M.H., Denny K.S.Ng., 2017, A Heuristic Framework for Process Safety Assessment during Research and Development Design Stage. Chemical Engineering Transactions, Vol 56, 2017, p 739-744.
Husserl E.G.A., 1969, Ideas: General introduction to pure phenomenology, p 116. UK, London: George Allen & Unwin.
Kingston-Howlett J., Dien Y., 2017, The McNamara Fallacy Blocks Foresight for Safety. Proceedings of the 53rd ESReDA Seminar, 14 – 15 November 2017, European Commission Joint Research Centre, Ispra, Italy.
Kirwan B., 2008, From safety culture to safety intelligence, p 18-23. In: Kao T. (Eds), Probabilistic Safety Assessment and Management Conference, PSAM9, 18-23 May 2008, Hong Kong.
Kleindorfer P.R., Belke J.C., Elliott M.R., Lee K., Lowe R.A., Feldman H.I., 2003, Accident Epidemiology and the U.S. Chemical Industry: Accident History and Worst-Case Data from RMP Info. Risk Analysis, Vol. 23, No. 5, p 865-881.
Klein G., Snowden D., Pin C.L., 2007, Anticipatory thinking. NDM8 - the Eighth International Conference on Naturalistic Decision Making. Asilomar Conference Grounds, Pacific Grove, California. www.academia.edu/522193/Anticipatory_thinking. [Accessed May 25, 2018]
Le Coze J., 2013, New models for new times. An anti-dualist move. Safety Science, Vol. 59, p 200-218.
Lindhout P., Reniers G., 2017, Risk validation by the regulator in Seveso companies: Assessing the unknown. Journal of Loss Prevention in the Process Industry (Special Issue 40-year legacy of Seveso), Vol. 49, Part A (September 2017), p 78-93.
Marion J.L., 2002, Being Given: Towards a Phenomenology of Givenness. Translated by Jeffrey L. Kossky. USA, Palo Alto: Stanford University Press.
Merleau-Ponty M., 1945, Phénoménologie de la perception. France, Paris: Gallimard.
Pawson R., Wong G., Lesley Owen L., 2011, Known Knowns, Known Unknowns, Unknown Unknowns: The Predicament of Evidence-Based Policy. American Journal of Evaluation Vol. 32, No. 4, p 518-546.
Peirce C.S., 1867, On a New List of Categories. Presentation to the American Academy of Arts and Sciences, May 14, 1867. In: Proceedings of the American Academy of Arts and Sciences Vol. 7 (1868), p 287-298.
Ramasesh R.V., Browning T.R., 2014, A conceptual framework for tackling knowable unknown unknowns in project management. Journal of Operations Management Vol. 32 (2014), p 190–204.
Reniers G., Amyotte P., 2012, Prevention in the chemical and process industries: Future directions. Journal of Loss Prevention in the Process Industries, Vol. 25 (2012), p 227-231.
Schwab K., 2017, The Fourth Industrial Revolution. USA, New York: Penguin Random House LLC. ISBN 9781524758868.
Slovic P., Weber E.U., 2002, Perception of Risk Posed by Extreme Events. Risk Management strategies in an Uncertain World. Conference paper, Palisades, USA, New York, April 12-13, 2002.
Swuste P., Reniers G., 2017, Seveso inspections in the European low countries: History, implementation, and effectiveness of the European Seveso directives in Belgium and the Netherlands. Journal of Loss Prevention in the Process Industries, Vol. 49 (2017), p 68-77.
Taleb N.N., 2007, The black swan: The impact of the highly improbable. USA, New York: Random house. ISBN 978-1400063512.
Taylor-Gooby P., Zinn J.O., 2006, Current Directions in Risk Research: New Developments in Psychology and Sociology. Risk Analysis, Vol. 26, No. 2, 2006, p 397-411.
Uraikul V., Chan C.W., Tontiwachwuthikul P. ,2007, Artificial intelligence for monitoring and supervisory control of process systems. Engineering Applications of Artificial Intelligence. Vol. 20 (2007), p 115–131.
Weick K.E., Sutcliffe K.M., 2007, Managing the Unexpected: Resilient Performance in an Age of Uncertainty. USA, San Francisco: Jossey-Bass.