Towards a Triple Loop Learning from Failures

Ashraf W. Labib[1]

[1] University of Portsmouth, Portsmouth Business School: Portland Street, Portsmouth, United Kingdom, Email Address: ashraf.labib@port.ac.uk

In this work a framework of learning and unlearning from failures is introduced through a model of three loops learning which is proposed and verified drawing on examples based on case studies that relate to major failures or disasters such as Fukushima, BP Deep Water Horizon, the Challenger, Bhopal and German Wings disasters. In doing so, we provide a new conceptualisation of learning from failures through triple loop learning model. In particular we argue that triple loop learning implies a paradigm shift. In this paper it is shown that such paradigm shift in safety science implies focus on possibility rather than on probability, and that reliability does not always implies safety. A three loop learning from failures where the three 'sights' model of : insight, foresight, and oversight is introduced.

I. INTRODUCTION

The general topic of organizational learning refers to a modified collective knowledge and routines as a result of the organization's experience. This field is very well established since the work of Cyert and March (1963) where they identified success programs, and decision rules as illustrative of learning based on routine, and the work of Levitt and March (1988) on organizational learning, where they stated that mechanisms for learning from experience are still largely unspecified. However, it is observed that no theory or model of organizational learning is yet considered to be widely acceptable, and according to Friedman *et al.* (2005), it remains to be a field characterised by conceptual confusion.

The concept of organisational learning can be described as a dichotomy (Tosey et al 2012; Cope 2003). Single loop learning occurs `whenever an error is detected and corrected without questioning or altering the underlying values of the system', and double loop learning occurs `when mismatches are corrected by first examining and altering the governing variables and then the actions', as defined by Argyris (1999: 68). Therefore, first order learning is about preserving and improving status quo, whereas, second loop learning implies changing the status quo itself. Accordingly, by extending this logic, triple loop learning can then be described as a `deeper', or `higher', level than, primary and secondary forms of learning, which implicitly means that this level has greater impact. Yet, as noted by Tosey et al, (2012) in spite of its perceived importance, conceptualisations of this level of learning do not always make clear how it differs from, or relates to, primary or secondary forms.

One of the most comprehensive conceptualizations of the organizational triple loop learning can be found in Tosey et al. (2012) in their paper titled 'The origins and conceptualisations of 'triple-loop' learning: a critical review'. They distinguish between three coneptualizations of 'triple-loop learning'. Conceptualisation precedes operationalisation, the former being at the level of theory and the latter at the level of research (Frankfort-Nachmias and Nachmias 1992).

In this paper we address the research level in terms of opertionalisation by providing tools and case studies as enablers for realising second and third loops of learning from failures. In doing so, it is hoped that such operationalisation in the safety science field will feed into refining the conceptualisation at the theoretical level. We also describe each of the conceptualisations of triple-loop learning into the context of safety science.

I.A. The Origins of the Conceptualisations of Triple-Loop learning

Tosey et al. (2012) note that whilst 'triple-loop learning' as a concept, has been inspired by the work of Argyris and Schon (1978), the term does not actually arise in any of their published works which continued until Argyris and Schon (2003). Taking the theoretical lens of Tosey et al (2012), they offer three conceptualisations of triple-loop learning a) a level superior to single and double-loop learning, a form of shift from operations to strategy; b) a level that involves reflexivity on learning how to learn about the previous two levels ie learning about the process of learning; c) a level that involves a change of epistemology; a change in the wisdom in the form of knowing and learning. In the next paragraphs we describe each of the conceptualisations and highlight its relationship with safety science domain and in particular the domain of learning from failures.

The first conceptualisation of triple loop learning is being beyond, or superior to, double-loop learning. The origins of such conceptualisation of triple-loop can be traced back to the work of Hawkins (1991) who uses the term 'treble-learning' to argue it as a step beyond the double-loop learning and proposes a 'beyond effectiveness thinking'. In the following year, Swieringa and Wierdsma used the term 'triple-loop learning' and this book has since them been widely cited as the origin of triple-loop learning, where they state that triple loop happens '*when the essential principles on which the organization is founded come into discussion…..the development of new principles, with which an organization can proceed to a subsequent phase'. Then in the following year Isaacs (1993), states that triple-loop learning `opens inquiry into underlying "why's."…that permits insight into the nature of paradigm itself*' (Swieringa and Wierdsma ,1992). It is then suggested that 'following Argyris and Schön's schema logically, since double-loop learning involves correction of governing variables, it would appear that triple-loop learning should be concerned with change in whatever governs those governing variables' (Tosey at al, 2012). This could be the `paradigm' using Issacs (1993) terminology. But what is a paradigm? Towill (1999), and cited by Alvi and Labib (2001), suggests that a paradigm: '(a) is a set of rules which establishes boundaries and describes how to solve problems within these boundaries, (b) influences our perception and aids organization and classification of the way individuals see the world, (c) is a model which aids comprehension of what the individual sees and hears, (d) may be seen as a set of unquestioned, subconscious business assumptions, (e) has the effect of a new beginning, i.e. is a new way of doing things'. Such conceptualisation has been proposed in many contexts such as measuring supply chain knowledge management performance, where single loop implies learning among individuals, double-loop is about learning among teams, and triple loop involves learning as an organization (Ramesh and Aslam, 2016). Now, in the area of safety science, Labib and Harris argue that in the after math of Fukushima nuclear power plant disaster, 'the emphasis should shift from 'probability' assessment to 'possibility' identification. Currently, the 'P' in PRA and PSA stands for 'probabilistic'. Mathematically, it is easier to formalise 'probability' than 'possibility', despite the fact that it is now clear, from Fukushima, that the main challenge concerns possibility, hence a paradigm shift is needed to conduct more research on modelling possibility' (Labib and Harris, 2105). In other words, there is a need for a paradigm shift with respect to risk assessment .

The second conceptualisation of triple-loop learning is when the emphasis is more towards the process of learning itself. Argyris and Schön (1978) introduced the concept of `deutero-learning' (`deuteros' in Greek language means second or secondary), which they define as 'to learn how to carry out single- and double-loop learning'. Therefore, learning to improve performance at an increasing rate relates to single-loop learning. Whereas learning to carry out the reflection on and inquiry into the governing variables, values and norms underlying organisational action, relates to double-loop learning (Tosey et al, 2012). According to Romme and van Witteloostuijn (1999), whilst single loop learning is about doing things right (an efficiency mind-set), and double-loop learning is about doing the right thing (an effectiveness mind-set), triple loop learning is more about capability in making well-informed decisions regarding strategy, objectives,. etc. Yuthas et al (2004) argue that triple-loop learning is about a reflection on the learning process in terms of the assumptions being made, and the value motivating the learning process. In the context of learning form failures, Labib (2014) suggests that a key learning lesson from BP Deep Water Horizon disaster is about assumptions being made about a fail-safe systems, the blowout preventer (BOP) that failed to operate. A fail safe system is a 'backup-up of the backups', a last resort in the event of a catastrophic failure. So the assumption that it is rarely used, should not mean that its design and maintenance is less important than other more frequently used equipment. A similar assumption occurred when deciding to let the Challenger take off relying on the assumption that in the event of a blow by a secondary O-ring will cover for shortcoming of the primary one, which was questionable. Another example of bad assumption being made was the case of Bhopal disaster where the refrigerator which was designed to keep the toxic gas MIC below 5 degrees centigrade was turned off to save electrical power expenses of 20 dollars per day and we now know that this mistake cost loss of lives of several thousand people. Here what needs to be learned (third-loop of learning) is to always remember that there were assumptions when a decision is being made and to be able to continually question the validity of such assumptions when the situation changes. Learning about the process of learning in safety science has been described by Labib and Harris (2015) paper titled 'Learning how to learn from failures', where the process of learning and gaining knowledge about learning from failures was explained. Labib (2015) then extended this work in the form of 'unlearning' where a comparison was carried out between Bhopal and Fukushima despite being originated from two different industries.

The third conceptualisation of triple-loop is based on Bateson (1973) Learning III which he defines as 'a corrective change in the system of sets of alternatives from which choice is made'. In Bateson's view this is analogous to a conversion in religious belief, or a change in character. Whilst the first conceptualisation is an advanced form of the second-loop learning, and the second conceptualisation is about reflexivity on how one learns, this third conceptualisation is about a complete change. This third conceptualisation involves scepticism about whether it is beneficial to do it, being beyond language, of a recursive nature, and involves risk in learning. According to Engestrom (2001), Bateson's LIII is a 'provocative proposal, not an elaborated theory' and being primarily theoretical and lacking empirical evidence as outlined by Tosey et al (2012). In the field of learning from failures, Labib (2014) offers a taxonomy of theories related to learning from failures where two opposing beliefs are being discussed. Such contrast in views is the nearest that one can think of to Bateson's LIII learning. For example, Labib compares between two opposing views; learning from case studies versus the narrative fallacy concept. On the one hand there is a school of thought which argues that learning from carefully chosen major disasters tend to encourage organisations and policy makers to learn from those incidents as argued by Desai (2010), and that we most fully appreciate what is being told as a tale as argued by Woods et al (1994). On the other hand, there is another school of thought that warns against the 'narrative fallacy' which argues that narrative fallacies arise from our continuous attempt to make sense of the world as suggested by Taleb (2010). Also Kahneman (2010) argues that this misleading assumption that the past has been fully understood can feed into a further illusion that everything is simple, and predictable, and hence controlled and that this has been observed in many business and consultancy focused books. The classical example of two opposing beliefs in safety science is the natural accident theory (NAT) contrasted with that of the high reliability organisation (HRO). Perrow (1984) coined NAT and argues that since complexity and tight coupling reduces resilience, then accidents – which are complex by nature – cannot be predicted or prevented and hence the term 'normal'. On the other hand proponents of HRO such as Rochilin et al (1987) argues that organisations can contribute significantly to preventing accidents and that the emphasis should not be on how accidents happen but what successful organisations do to ensure safety in complex systems. The NAT reveals a dark side, whereas HRO is more optimistic. The same dark side can be said about the whole idea of Batteson's Learning III as he suggests that an attempt at LIII can be dangerous and result in an unintended consequences and profound 'organisational unlearning' as argued by Tsang and Zahra (2008). What is really missing from all the previous conceptualisations is an 'empirical work to test and develop each of these conceptualisations…this dearth of empirical research needs to be addressed' (Tosey et al 2012).

I.B. The Misconception of Triple-Loop learning

It has been noticed in the literature that sometimes a misconception of what constitutes triple-loop learning. For example, the work of Lassey (1998) has been criticised by Tosey et al, where a triple-loop learning is described as where `the role or the mission of the organization is questioned', and provides an example of managers deciding to change the nature of their business from a fast food outlet to a café (Tosey at al, 2012). This is problematic in the view of Tossey et al since 'changing the nature of a business does not necess arily constitute even double-loop learning; it therefore mistakes a change in external circumstances for change in values or principles' (Tossey et al, 2012).

Another misconception is related to whether deutero-learning is simply Argyris and Schon's terminology of the conceptualisation of third loop learning. Tosey et al (2012) points out that this is not the case. They cite a recent work by Argyris (2003) where he argues that deuteron-learning is a 'meta' to single or double-loop learning, and he also stresses that the skill required for double-loop learning are more advanced than those required for deutero-learning on single-loop issues.

2. LEARNING FROM MAJOR DISASTERS:

There is evidence that the lessons from major disasters have not always been learnt by institutions such as governments, the market and the industry. It has been noticed from the analyses of most major disasters that incorrect assumptions have been made, early warnings have been ignored, and the scale of what could go wrong have been misjudged (Hatamura, 2011). These shortcomings need not be viewed as just individual professional or technological failures. Rather, learning can be viewed as the outcome of the organizational and institutional contexts that support or inhibit it (Maslen, 2014).

2.A. The Case of Triple Learning Loop in Nuclear Disasters

Aoki and Rothwell studied the Fukushima nuclear disaster from a comparative institutional perspective. They identified three possible nuclear organizational structures: modular, vertical and horizontal. They then mapped these structures to three nuclear accidents (TMI, Chernobyl and Fukushima), and analysed them with respect to the prevailing American, Russian and Japanese management structures as regards preparedness and responsiveness to shocks. They found that while the typical Japanese mode of work is ideal in stable situations of 'Just in Time', this may not be effective in 'Just in Case' situations, such as a nuclear disaster. They also argued that there is a need to study the Chinese model given the ambitious plans for expansion in nuclear power plants (NPP) and the risk involved in employing nuclear reactors from different suppliers (5 nuclear suppliers as compared to the 2 nuclear suppliers in Japan and the UK). They warn that unless China, as well as other countries where new nuclear power plants are being or will be built, establishes a strongly independent and highly professional nuclear safety commission, its quest for safe nuclear power could be derailed by another accident, given that any nuclear accident is a global disaster due to its wide impact (Aoki and Rothwell ,2013). Such analysis of classifying the nuclear disasters and mapping them against three corresponding management cultures is a move towards higher learning loops.

Another example of enablers for transition to a higher learning-loop can be observed from the concept of defence-in-depth in NPP, which is a significant safety principle and it is proposed that all system safety practitioners should be aware off (Saleh et al, 2014). Defence-in-depth originated from military strategy as a diversification strategy for protection of important positions by multiple layers of independent defences (Weightman, 2013). Since then, the nuclear industry has been one of the first to adopt defence-in-depth concept, and it became the industry standard for risk-informed decisions by the U.S. Nuclear Regulatory Commission (Sørensen, Apostolakis, Kress, & Powers, 2000). The main features of the barriers in a defence-in-depth concept are: diversity (should not rely on just physical defences), redundancy (parallel rather than series configurations), segregation (apart from each other), and no single point failure (the depth element).

Combining both views of Weightman (2013), and Saleh et al (2014) the order of the safety barriers should be as follows: First, to minimise risk through prevention of occurrence. Second, mitigation of the consequence. Third, transformation of the risk (if feasible so that others can act on the behalf of the victim e.g. the insurance concept). Fourth, respond (or absorption) as a final resort for containment to minimise potential adverse consequence of the failure. As with decisions related to any safety barriers, there is always a trade-off between number of barriers and cost. Accident consequences, as a measure can help prioritize accident pathways and identify where additional barriers within a defence-in-depth strategy (Saleh et al, 2013; Minarick, 1990). According to Kurokawa (2011) investigation report, '*the defence-in-depth concept used in other countries has still not been fully considered [in Japan]'*.

As an outcome of Fukushima nuclear disaster, generic lessons can also be considered as enablers for moving towards higher levels of learning. The first generic lesson is about too much belief in previous successes. Ironically, experience with success can be counterproductive. This has been true throughout history of disasters. For example, too much belief in the 'unsinkability' of the Titanic meant it set sail with too few life boats and those that were installed were there only to rescue people from other ships. It was this false perception that led to the fatal error of providing insufficient life boats. How does this apply to the Fukushima disaster? Too much belief in the safety of nuclear power in Japan led to some weaknesses in the perceived resilience. According to Kurokawa (2011) investigation report, the Japanese regulatory body Nuclear and Industrial Safety Agency (NISA), informed the operators that "*they did not need to consider a possible station blackout (SBO) because the probability [of a tsunami to reach that level] was small and other measures were in place*". In the same report it is also stated that "*As they [the regulators] had firmly committed themselves to the idea that nuclear power plants were safe, they were reluctant to actively create new regulations*".

The second generic lesson is about misunderstanding fashionable paradigms. According to Labib, the misconception of fashionable paradigms might be one of the reasons why man-made disasters happen. Such misunderstanding can come in many forms, including, for example, misunderstanding of 'lean' management. The concept of Lean Thinking, or Lean Manufacturing, is often misinterpreted as a cost cutting exercise, 'taking the fat out of the meat'. Organizations, in an attempt to identify and minimise waste can go too far and end up unknowingly sacrificing safety (Labib, 2014). Cutting cost is just one aspect of lean thinking; it is also about adding value and streamlining a process. According to Kondo (2014), who is the former Chairman of Japan Atomic Energy Commission (JAEC), "*the 'Quality First Culture' distorted the perception of safety in Japan. Promotion of Quality Circles (QC) activities ie Kaizen (Continuous improvement) initiatives in nuclear* *industry in Japan in the 1980's, which resulted in efficiency gains such as low scram frequency, low fail to start probability of EDGs [Emergency Diesel Generators], and low defective fuel element rates, led to a misconception of success. Such perceived success gave rise to nuclear safety myth: a trouble-free nuclear power station designed based on DBEs [Design Basis Earthquake] is safe*".

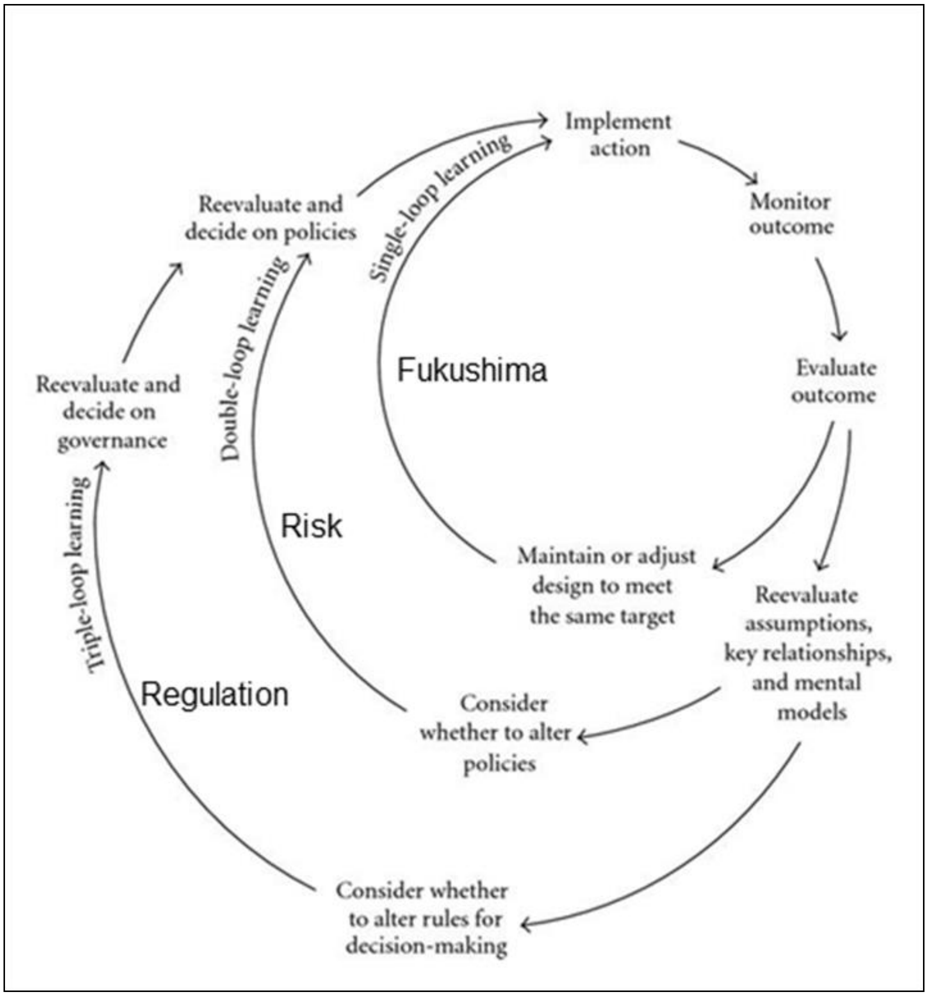

Figure 1: Three-loop learning in NPP based on Fukushima nuclear power disaster.

Triple loop learning:

Figure 1 shows the triple-loop learning from the Fukushima nuclear disaster. The 1st loop learning here is about the ability to maintain or adjust design to meet the same target, and in NPP as an outcome of the Fukushima disaster, this is related to double-jeopardy (i.e. more than one failure mode occurring simultaneously). Also, the first learning loop from Fukushima nuclear disaster is about assessment of interdependencies and ability to model combinations of multiple cascading hazards. It is now clear from the accident that there was inadequacy of risk assessment for vital assets to respond to an earthquake and a tsunami. Simulation and what if analyses are crucial enabling technologies for coping with such challenge. In the case of Fukushima, simple equipment, such as mobile generators and battery packs could have helped prevent the meltdowns. Simple design improvement solutions such as fitting water proof seals on all doors in the reactor building, or placing an electricity-generating turbine on the facility's roof, where the water might not have reached it, would have prevented such disaster.

The 2nd loop of learning is about consideration of whether to alter policies. In the context of Fukushima, it is related to regulation of the NPP industry. Prof Kurokawa blames what he calls "regulatory capture", a process by which the nuclear power industry "captured" the bureaucracy that was supposed to regulate it. The close relationship between senior bureaucrats from Japan's nuclear regulator and nuclear industry created a sort of conflict of interest environment. In the wake of Fukushima disaster, it has been proposed that the time has come for more independence and global governance for the whole industry towards a global independent nuclear safety commission, in order to separate national economic and political interests from the regulatory function, in promoting nuclear power, something which concerns all nations (Labib, and Harris, 2015). Therefore, the remit of the IAEA should shift from an advisory body to a licensing function for nuclear power plants with authority to make legally binding decisions.

The 3rd loop learning is about consideration of whether to alter rules for decision making. In the context of Fukushima it is related to a paradigm shift from emphasis on probability to possibility when assessing risk. Is a shift in mental modeling where there is a need to move from problem solving to problem structuring mentality. The '*possibility*' of the two such concurrent natural hazards occurring at high magnitude and their cascading impact was not understood by decision makers. Poorly informed political decisions significantly affected mitigation resources, infrastructure vulnerability and institutional preparation. It is also about a shift from uncertainty of the hazard to uncertainty due to lack of knowledge.

2.B. Triple Learning Loop - The Case of German Wings Accident

The Germanwings plane flight 9525 had been flying from Barcelona to Duesseldorf on 24 March, 2015. All 150 people on board died after a crash in the mountains. Earlier findings from the cockpit voice recorder suggested Lubitz – the co-pilot, locked the pilot out of the cockpit. The German prosecutors said internet searches made on the tablet found in Lubitz's Dusseldorf flat included "ways to commit suicide" and "cockpit doors and their security provisions". So what we now know is that the Germanwings plane have been deliberately crashed by the co-pilot, with the pilot locked out of the cockpit. But how could such scenario occur? The answer is because in the wake of 9/11 attacks cockpit doors in all aeroplanes were secured and made stronger to prevent terrorists gaining access through a locking mechanism. Such locking system means that the door cannot be entered unless the pilot inside allows someone to enter. A touchpad will allow cabin crew who know the code to enter if the pilot is incapacitated. However, the pilot in cockpit can also deny entry even if someone enters touchpad code, in case the code is obtained by force. Now this is exactly what happened in the case of Germanwings accident where the co-pilot who was alone in the cockpit denied entry from inside the cock-pit.

The possibility of such an accident was not new as similar scenarios occurred in the past two years prior to the accdient. In March, 2014, Malaysia Airlines Flight 370 crashed killing all 239 passengers and crew. Pilot suicide is a possibility although the black boxes have not yet been found. In November 2013, LAM – Mozambique Airlines Flight crashed killing 33 passengers and crew. The pilot intentionally crashed jet, where the co-pilot was locked out of the cockpit, according to the voice recorder, an exact replica of the scenario of Germanwings. So one can model the Germanwings disaster to be attributed to three factors: a) poor door design, the door is hard to break through, and the code access can be over ridden, b) lack of safety procedures since here was only one person left in charge of the whole airplane, where there is no other way to control the plane, and c) poor learning culture across the whole industry, where there is evident that such scenario has occurred in the past.

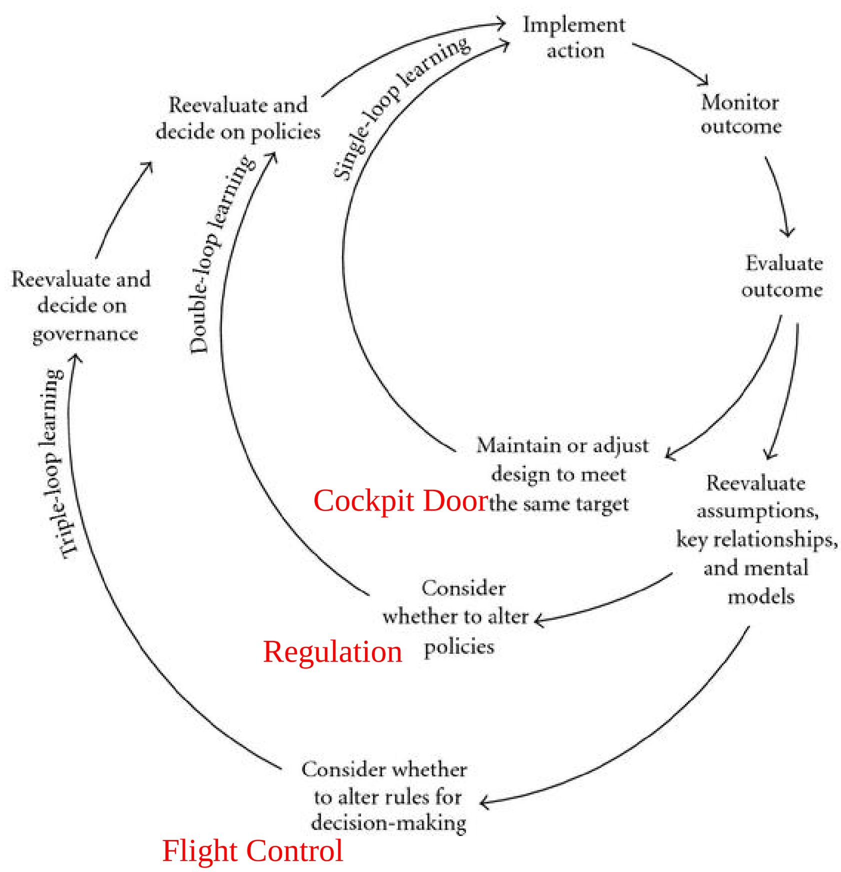

Figure 1: Three-loop learning in planes based on the Germanwings accident.

Here the 1st loop learning related to reliability and redundancy (i.e. Redundancy can increase the reliability for one failure mode but at the expense of another). This is a classic case of interdependence among failure modes. In protecting the cockpit, we lost the whole plane. The 2nd loop learning is related to regulation of the aviation industry. A 'What if' (sensitivity) analysis ought to have taken place triggered by past occurred scenarios which should have acted as early warning to the aviation industry and therefore, a more global governance is needed where the idea is to look at means of learning from such scenarios. One can argue that we already have such arrangements among civil aviation institutions, but clearly this did not work well to prevent the Germanwings accident. The 3rd loop of learning related to a paradigm shift from emphasis on probability to possibility when assessing risk. So reliability does not equal safety, and the idea is to insulate the cockpit (in the wake of September 11th), but not to isolate it as in the case of Germanwings accident.

3. DISCUSSION

Based on the case studies investigated, the information flow with respect to the triple loop learning can be in the form of addressing the three 'sights' viz, insight, foresight, and oversight. Insight which constitutes the first learning loop implies assessing reality, data and information. Foresight which constitutes second loop learning implies knowledge and better decisions. Whereas the third learning loop of oversight implies a deep understanding of the disaster and can be characterized as reaching a wisdom state.

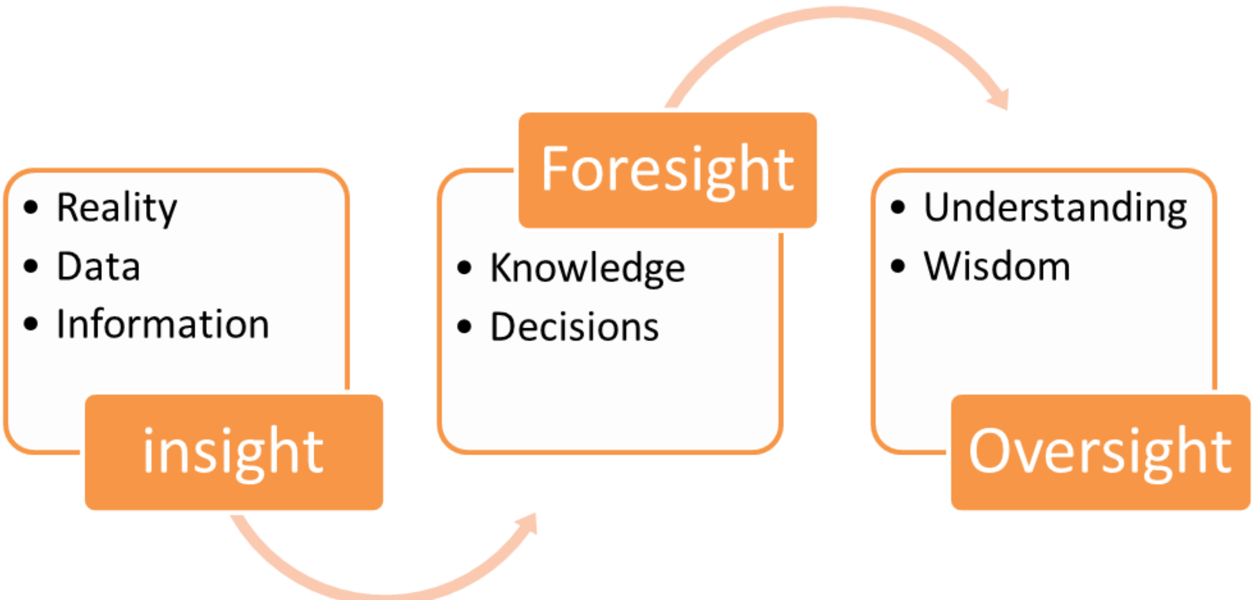

Figure 3: The proposed three loop learning from failures.

4. CONCLUSIONS

In this paper we conceptualized the triple learning loop. In particular we applied in to the case of learning from failures. We showed examples from major failures where demonstrated the paradigm shift in safety science in the form of two main issues. The first paradigm shift is from probability focus to possibility focus. The second paradigm shift is that reliability does not necessarily equate to safety. We then proposed a three loop learning from failures where the three 'sights' model of : insight, foresight, and oversight was introduced.

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