PREDICTING AND PREVENTING ORGANIZATIONAL FAILURE: LEARNING, STABILITY AND SAFETY CULTURE

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Abstract

The physical definition of “safety culture” is the creation of an organizational and operational structure that places unending emphasis on safety at every level. We propose and prefer the use of the term and the objective of *sustaining a “Learning Environment”,* where mistakes, outcomes and errors are used as learning vehicles to improve, and we can now define why that is true. Therefore we can *manage and quantify* safety effectively tracking and analyzing outcomes, using the trends to guide our needed organizational behaviors.

1. Safety Management and Culture: Creating Order Out of Disorder

All events, accidents, errors and outcomes occur because of human involvement and mistakes, and are due to and include organizational and management failures. Sometimes these can be on a massive scale, and often cause massive inquiries into cause and blame. It is customary and popular today to blame a lack of corporate or company “safety culture” for the cause, with the concomitant management failings of no safety awareness, poor staff training, insufficient safety emphasis, inadequate budgets, emphasizing production over safety concerns, violations of operating rules and procedures, etc., etc.. The word “culture” here is used as a convenient sociological shorthand for the milieu, environment, attitudes, approaches, norms and values that exist in any company’s facility, organization, management or boardroom.

One simple worldview is that at least 90% of events (outcomes) are really due to management causes, organizational failures and human decision making issues, which we regard here as simply categorized as insufficient learning at the homo-technological system (HTS) level. To solve that problem, the attributes of a desired organizational “safety culture” have been defined and investigated in a number of ways, primarily based on structured surveys, interviews and questionnaires. The idea is to provide a qualitative measure or idea of how staff and management really feel and act about safety, which we regard here as some implied elimination of the error states. There are no equations and no theory: it is social science and psychometrics applied to safety. To paraphrase Howlett [1], these many, varied and persistent factors all constitute and represent the common inadequacies behind “loss of control”. We have recently summarized multiple case studies and derived objective measures for tracking safety culture and organizational learning, including how to *predict* and prevent outcomes, and identify the concurrent common failings and legal responsibilities of management [2].

Creating order is exactly also the intent and function of “Safety Management Systems” (SMS), which are so popular today. The emphasis is then on the artificial creation of a “safety culture”, coupled to an imposed organizational structure, which places unending emphasis on safety at every level. We propose and prefer the use of the term and the objective of sustaining a “Learning Environment”, where mistakes, outcomes and errors are used as learning vehicles to improve. Detailed “guidance” on SMS has been issued by many regulators in the commercial aircraft-industry [3, 4, 5]. One item or tool is a “risk analysis matrix” of “Severity versus Probability”, where one has to enter minimum, moderate, and high-risk levels using a numerical scale based on judgment. The idea is to find some relative ranking and prioritization of issue importance and/or urgency, and the need is obvious for quantification and numbers.

We are still faced with how to quantify what all this means in terms of risk prediction and reduction, other than we know if we do not learn we have more risk.

2. Safety Culture and Safety Surveys: The Learning Paradox

Recent major events in multiple technologies and industries highlight real problems, such as in aerospace (Columbia Shuttle loss [6], nuclear (Davis-Besse plant vessel corrosion) [7], oil (Texas City refinery explosion) [8] chemical (Toulouse ammonia plant explosion) [9] and transportation (the Quebec overpass collapse)[10]. These events have caused a spate of "safety culture" studies and surveys, and retroactive revisions to safety inspections, incident reporting and facility siting legislation. The application of such pseudo-psychological survey or audit approaches to evaluating "safety culture" in HTS has been quite common in the nuclear and other industries. Recent real-life examples examined the human, management and non-mechanical factors contributing to the circumstances that lead to undetected severe pressure vessel corrosion in a nuclear power plant (the Davis-Besse event) [11]) and the undetected overfilling and explosion for a major US refinery (the Texas City event) [8,12]. The incidents were, as always, clearly avoidable, but apparently happened due to management emphasis on production rather than safety, and gaps in the operating and inspection requirements. Hence, there was and is a clear desire by the regulator to "fix" the management system; and by the owner/operator to also correct any perceived and actual problems that caused safety priorities to be neglected.

Similarly there has been a recent thrust to identify the "resilience" of an organization, entity or corporation [13], meaning its ability to remain stable under strain and stress. Examples might include emergency room overloads, and/or the response to terrorist attacks. These latter are exemplified by Mayor Rudolph Giuliani's precept of "relentless preparation" for handling the 9/11 attacks on New York [14], where a patchwork of effective emergency management measures was stitched together from prior training, drills and emergency response plans for quite different scenarios.

But this whole conceptual structure and qualitative descriptors desperately need quantification and indicators based on actual data, together with correctly chosen performance measures. Otherwise these fine but illusive attributes of a safety culture, organizational stability and failure potential only represent a desired view of a "we will know one when we see it" condition; or a preferred, idealized and relative "state of being" or simply an unknown unrealized desiderata.

In our view, and so say the actual outcome data, a "learning environment" is the very foundation of all these needed partial attributes of and improvements to a safety culture and organizational success in any HTS. Our proposition, theory and argument makes learning the needed priority, objective and goal that underpins everything, and which all the others should support.

3. Never Happening Again: Perfect Learning

After any serious observed outcome, an accident, industrial injury, reportable event, lost time incident, almost inevitably, as inevitable as the events themselves, inquiries and retribution are invoked to discover what happened, and what went wrong. The phrase invariably used is: "So we can be sure that it will *never happen again*". That ideal goal is the complete elimination of an error state, and the implied reduction of the risk to zero for the causes of the prior observed or similar outcomes. The learning process from the outcome is, in our terminology, called "perfect learning". Interestingly enough, this limit of ideal risk reduction has a theoretical result that can be derived simply by assuming that we learn from all the prior non-outcomes, hence reducing the future likelihood.

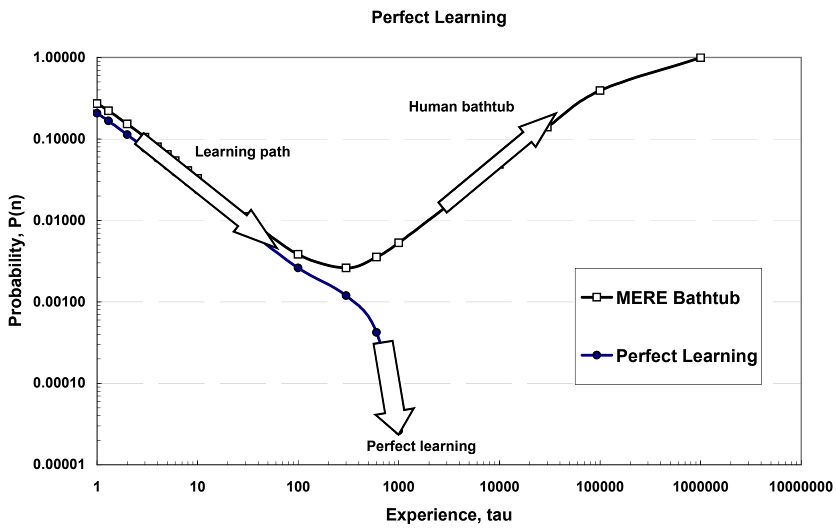

Figure 1 The Learning Paths

The Minimum Error Rate Equation (MERE) human bathtub curve and the perfect learning limit are both shown in Figure 1 [2]. The path shows a fork: the one labeled as "perfect learning" is the result of learning from all non-outcomes, or so-called "near-misses", as well as from outcomes. We follow the usual MERE learning hypothesis path that is the "human bathtub", until the divergence caused by the catastrophe of single outcome. Since we now learn everything, with "perfect learning", the subsequent probability is essentially zero. The rapid decline is caused theoretically and mathematically by a triple exponential term, which physically arises due to superimposing or compounding the prior double exponential of the "human bathtub" with another exponential due to the sampling likelihood probability. *Unfortunately, no data in the world follow such a perfect learning path*, unless of course, the HTS is destroyed as a direct result of this first and only outcome. The only known case is for the *Concorde* aircraft, which was withdrawn from service before a second catastrophic event could occur.

The approach for an effective SMS must include the elements of success based on the attributes of a learning environment. The US Navy nuclear ship and submarine programs set the highest standards of manufacture, operation and training. Charles Jones [15] showed how that successful Navy endeavor, contained the major elements to identify and resolve outcomes and errors, with management structure literally turned on its head. Jones gave the following classic definition of a good safety culture: *"The integrated body of specific characteristics and personal attitudes, which together ensure that problems are aggressively sought out, and that all concerns and issues raised are promptly addressed in a way that maximizes worker …(and) public safety"*.

Managers and operators need to know how good is their safety management system that has been adopted and used (and paid for), and whether it can itself be improved. We have shown the importance of accumulated experience in correctly measuring and tracking the decreasing event and error rates [2]. The rate of improvement constitutes a measurable "learning curve", and the attainment of the goals and targets can be affected by the adopted measures. The available data on significant events, reportable occurrences, and of loss of availability suggest the use of learning curves as a means of accurately tracking progress; and stress the importance of a sustained *learning environment* in performance improvement.

4. Predicting Event Rates and Learning Curves using Accumulated Experience

It is important to provide a theoretical basis for these trends in order to intercompare these apparently disparate data. The general hypothesis we make, in accord with all the available data, is that humans learn from experiencing the events that occur as a result of mistakes and errors, and this learning appears as reducing system outcome rates with increasing experience. We can take the rate of learning (event or error rate reduction) as proportional to the instantaneous event or error rate. The exponential model form that follows from that hypothesis, is obtained using the analogous classic formulation from failure rate modeling but using the accumulated experience and allowing for a finite asymptotic (non-zero minimum) rate.

We can define a non-dimensional outcome rate, E*, normalized by the rate A_o* of the initially observed events or errors when the technology began or at the start of reporting. Thus, we have the non-dimensional event or error rate, E*, given by the Universal Learning Curve (ULC):

$$E^* = A^*/A_o^* = \exp - KN^* \qquad (1)$$

where $A_o^* = (1\text{-}A_m/A_o)$ and $A^* = (1\text{-}A_m/A)$, N* being a measure of the accumulated experience, and k, is the learning rate constant. By renormalizing to the physically based parameters of the initial and asymptotic minimum accident rates, we have derived a workable intercomparison basis using *accumulated experience* as a measure of the technological system maturation.

5. Organizational Failure, Learning and Safety Culture: The "H-Factor"

The physical definition of "safety culture" is the creation of an organizational and operational structure that places unending emphasis on safety at every level. We propose and prefer the use of the term and the objective of *sustaining a "Learning Environment",* where mistakes, outcomes and errors are used as learning vehicles to improve, and we can now define why that is true. Therefore we can *manage and quantify* safety effectively tracking and analyzing outcomes, using the trends to guide our needed organizational behaviors.

The intent is to reduce the probability of occurrence of undesirable failures, events and crises, and the relevant measure of uncertainty is the information entropy, H. This H-factor is well-known in statistical mechanics where it is called the "uncertainty function" (see e.g. W. Greiner 1997 [16]). It has some key properties, namely: "as a fundamental measure of the predictability of a random event, which also enables intercomparison between different kinds of events". This property is exactly what we would require to assess a SMS's effectiveness in reducing outcomes as they emerge. Its obvious application to safety management *measurement* is however totally new as presented [2] and arises quite naturally from the need for management to create order from disorder. We have already demonstrated how this H-factor measure may be applied to safety indicators to determine the presence of learning [2,17].

Organizational stability is then naturally given by the ability to cope and provide order out of chaos also at the heart remaining "organizationally stable" against unexpected and large stress and unexpected occurrences. This same question and issue of system stability under stress also has direct application to the subjective and somewhat topical concept of "resilience engineering", where "… resilience is the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operation after a major mishap and/or the presence of a continuous stress" [13]. We can establish a new numerical measure for managing risk and predicting success, in terms of the ability to cope and manage the impacts of events, whether internally or externally caused. The argument heuristically assumes that an equivalence exists between the emergence of order (i.e. learning patterns) in physical, mathematical and HTS. By a physical analogy, the approach links the emergence of learning in human organizations and entities with recent ideas of the emergence of order and structure from chaos in the physical sciences [18].

The fact is that the incremental change in risk, as measured by changes in the information entropy, H, with changes in probability must reduce in any increasing experience increment. Therefore, the incremental change of information entropy, with changes in outcome probability must be negative, or $dH/dp \leq 0$. Translating this to experience basis, we can show [2] that the criterion *requires* that a stable (or "resilient") organization is and must be a learning organization.

6. Concluding Observations: Why Uncertainty Persists

It is management's expressed aim and intent to create order from disorder, which it can *only* achieve by decreasing the information entropy. Most safety managers are trained in traditional industrial safety methods and health and safety requirements, corporate officers are familiar with the world of business and accounting decisions and risks, and regulators are surrounded by a paper world of accident prediction, safety analysis, permitting and licensing that follow formal requirements and guidance. Therefore, the concept of entropy and disorder, let alone information entropy, is entirely unfamiliar as an objective measure of safety culture, organizational learning, safety management effectiveness, and outcome uncertainty.

However, it is simple to communicate the *concept of the learning hypothesis* and the impact on organizational learning, that it should be possible to obtain the management, corporate and regulatory buy-in needed to adopt the key elements of this new approach to assess risk and safety and the probability of success and of failure.

7. References

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