

Journey to a Definition of Chance

The role of chance in accident causation

By William M. Montante

IF A JOURNEY BEGINS with one step, discovery begins with a question. Asking one seemingly simple question, "What is chance?" launched a journey of discovery down new and unexpected paths. Choosing one path offered opportunities to explore others, ultimately leading to a deeper understanding of chance and its role in the causation of hazard-related incidents. What follows is a compressed travelogue.

The seed of the question sprouted from the investigation of a fatal hazard-related incident (Hazrin). As thorough as the investigation was, a complete understanding of causation seemed just out of reach. Gaps in causation are no surprise to most SH&E professionals. Making assumptions and taking steps toward corrective actions or control with a less-than-complete picture is an acceptable, often unavoidable compromise. Windows of opportunity will close if the search is carried too far or too long in an attempt to gather every piece of evidence, trace every cause to its root.

However, could what remains just beyond reach, the missing puzzle piece, the gap in the weave of understanding, in essence be chance? If chance played a role in the fatal Hazrin, what was that role? Why, when or how did chance enter the equation? Chance exists . . . or does it?

Certainly, the effects of chance-outcomes are visible and tangible. So it seemed logical that given enough time to backtrack causation along all possible paths, eventually chance would be confronted. From there, one would likely be able to describe, define and conceptually grasp it. However, if chance cannot be described in meaningful terms, how can an SH&E professional be expected to understand, manage or control it? On the

other hand, is control an illusion? One question cascaded to many.

The reader who has not dismissed this as simply a fanciful journey might still be thinking, "Why bother defining chance? I



use the word in everyday conversation though I might not be able to define it. I accept that it exists. Why the effort, and for what purpose?" The only appropriate rebuttal is "Zum Erstaunen bin ich da" (*I am here to wonder*) (Fortey 322).

The Journey Begins

Chance is a common word in everyday conversation. Related words such as luck, accident, fortune or serendipity are found in all languages. Chance has both positive and negative connotations, and there are degrees of chance (see pg. 37). People say, "Take a chance." "I had a chance encounter." "He took a chance." "Play a game of chance." "To happen by chance." "Your chance of winning is. . ." "This is your last chance." "She's getting a chance at her dream."

The pugilist has a fighting chance, the

athlete a sporting chance. Nat King Cole sang, "Chances are . . ." and John Lennon pleaded "give peace a chance." When trying to understand a seemingly improbable or emotionally painful event, people often ask, "What was the chance of that happening?" Other times, while preparing for action or seeking some desired outcome, the gambler or risk-taker might ask that same question in an attempt to foresee future possibilities. Serious gamblers can subscribe to *Chance*, while those who crave numbers can read *Chance News*. Others intrigued by the paranormal or metaphysics can watch "Beyond Chance," a television series on the Information Network.

Chance & the Creative Process

As an instrument of the inventive and creative processes, chance has extended a helping hand in many important innovations and scientific discoveries. Mark Twain once wrote, "Name the greatest of all inventors. Accident" (Chowder 96). Discoveries often occur when least expected, as this short list of serendipitous discoveries illustrates: penicillin, the worldwide web; microwave oven; Teflon™; Popsicle™ (originally "Eppsicle"); ketchup; Post-It™ Notes; cotton gin; vulcanized rubber; matches; and corn flakes (Slowiczek and Peters).

Dean Kamen, inventor of the Segway™ Human Transporter, captured elements of a definition of chance when he described the inventive process as "blindly frenetic. . . . When the light bulb in your brain suddenly goes off you might not even see it. . . . You get this *spaghetti bowl of paths* [emphasis added] and dead ends and changes in perspective and requirements and expectations, and sometimes you're lucky and you end up at the *inter-*

section of a technology that's right and works . . ." (Chowder 95). "Crucial crossroads were decided on a turn of chance. And no doubt, a different turn would have had a quite different consequence" (Fortey 99).

In *Chase, Chance and Creativity: The Lucky Art of Novelty*, Dr. James Austin, professor emeritus of neurology at the University of Utah, investigated how chance facilitates the creative process. Through a series of examples and personal experiences, he journeyed to his own definition of chance. Along the way, he discovered four distinct types of chance and personalities that typically must be present for creativity to occur (Table 1). It might be a worthwhile exercise to extrapolate Austin's types and personality traits specifically to the SH&E profession in order to enhance the understanding of chance, causation and control.

Quantifying Chance

Cutting-edge companies strive for a six sigma level of process control, getting as close to zero defects as possible. Even at that level, however, 3.4 defects or chance-opportunities per million remain. Statistical process control charts use upper and lower controls to bound the limits within which chance can wander unnoticed, waiting for the right moment to emerge. Deviation outside those limits connotes a special cause, not assignable to chance. Within those limits, chance can reveal another of its characteristics: randomness—that unpredictable, chaotic, indeterminant nature of the system, a machine or a person to drift from the expected path. "I have trodden but one of countless possible paths" (Fortey 317).

Chance is often used interchangeably, and perhaps incorrectly, with probability. Laws of probability quantify chance, and provide a degree of certainty, likelihood or measure of the confidence that something will happen (Bernstein 43; Orkin 19). For example:

- 1-in-a-million chance;
- 4-to-1 odds;
- life expectancy of 75 years;
- 90-percent probability of an accident;
- 1 failure in 35 missions.

Each statement represents

the number of occurrences relative to the total number of possibilities. Although necessary for quantifying chance-outcomes, reliance on probability and mathematical expressions still falls short of a workable definition of chance.

Questions Continued

As this journey continued, it became evident that chance is a construct of universal proportions. There seemed to be no scientific, philosophical, sociopolitical or religious schools of thought in which chance was not an influence in some way. As the list on pg. 38 shows, many domains or "doorways" were opened, many paths were crossed and many stops were made along this journey. It seemed improbable that someone or some discipline had not grappled with and resolved a definition of chance. "Two roads diverged in a wood, and I—I took the one less traveled by, and that has made all the difference" — Robert Frost's "The Road Not Taken."

For the curious SH&E professional, a logical resource might be *The Dictionary of Terms Used in the Safety Profession*. Surprisingly, a gap exists where the word "chance" would alphabetically appear. Is this an oversight? Does its absence imply that chance should not be part of safety's lexicon? Many safety textbooks and other references are similarly lacking, while others come close, only to sidestep a workable definition of chance. Given this, is chance a term to avoid because of its abstract

Degrees of Chance

- Best chance
- Fat chance
- No chance
- Good chance
- First chance
- Bad chance
- Second chance
- Only chance
- Last chance
- Pure chance
- Slim chance
- Blind chance

Table 1

Types of Chance & Necessary Personality Traits

Chance Type	Descriptor	Elements Involved	Personality Traits
I	Accident	"Blind luck." Chance events happen and nothing about the event outcome is directly attributable to the recipient.	None
II	General exploratory behavior	Chance favors those in motion. Events are brought together to form "happy accidents" when you diffusely apply energies in motions that are typically nonspecific.	Curiosity about many things, persistence, willingness to experiment/explore.
III	Sagacity	Chance favors the prepared mind. Some special receptivity born from or shaped by past experience permits you to discern a new fact or perceive ideas in a new relationship, then to comprehend their significance.	A background of knowledge based on your abilities to observe, remember and quickly form significant new associations.
IV	Personalized action	Chance favors the individualized action. Fortuitous events occur when you behave in ways that are highly distinctive of you as a person.	Distinctive hobbies, personal lifestyles, and activities peculiar or unique to you, especially when they operate in domains seemingly far removed from the area of the discovery.

Source: Austin, J.H. Chase, Chance and Creativity.

Domains of Chance

- Artificial intelligence
- Chaos
- Complexity
- Cybernetics
- Determinism
- Economics
- Emergence
- Evolution
- Game theory
- Genetics
- Information theory
- Literature
- Network theory
- Newtonian mechanics
- Parapsychology
- Philosophy
- Probability and statistics
- Quantum mechanics
- Risk management
- Safety
- Superstition
- Synchronicity
- System dynamics
- Theology
- Thermodynamics
- Warfare

nature—something to be kept apart from what SH&E professionals say and do? Is it an irritating obstacle to accurate investigation? Is chance an empty word used to conceal ignorance (Rastrigan 12)? Are practitioners less professional by using the word or by even admitting that it exists as a tangible element of causation? "*Suam habet fortuna rationem*" (*Chance has its reasons*)—Petronius.

Most dictionaries define chance as being derived from the old French "la cheance," which has its root in the old Latin *cadere*, "to fall," implying that it is natural for things to fall, to become chaotic, to settle out or occur by accident. In its noun form, chance is "the abstract nature or quality shared by unexpected, random or unpredictable events (luck); the likelihood of occurrence of an event (probability); an unexpected, fortuitous, random or unpredicted event (an accident); an opportunity; necessity." Aristotle defined chance, luck or accident as the incidental production of some significant result by a cause that took its place in the causal chain incidentally, and without the result in question being contemplated. In "Chance in Art: The Necessity, or Not, of a Definition," Brenneman followed threads of Aristotle's definition when she described chance as "something that happens unpredictably without observable human intention or observable cause."

However, the "something" in Brenneman's definition is an outcome or an effect of chance, not chance itself. As for Aristotle, his reference to "a cause," the "causal chain" and "some significant result" similarly offers only parts of a def-

inition. Any of these definitions might have satisfied the curiosity, justifying an end to the journey. Descriptive though they are, these definitions fall short of illuminating chance in a manner that might be more functional and insightful for SH&E professionals.

Nonetheless, some professional relevance is gained from acknowledging that there is a need to understand and appreciate the realm and reality of chance, and its ability to "unpredictably" influence the course of causation "incidentally" leading to desired or unexpected outcomes. Therein lies the opportunity. Appreciation leads to respect, and understanding leads to effective control of Hazrins. Defining a term or concept moves the discussion beyond the abstract toward a realization of what the challenge is. Chance is a real and relevant influence in everyday lives as well as the SH&E profession.

Chance in Literature & History

Literature, poetry, prose and music are replete with direct and metaphorical references to chance. One of the earliest documents referencing chance mechanisms was written more than 3,000 years ago—the Vedic poems of the Rgveda Samhita, called the "Lament of the Gambler" (Bennett 23). A medieval poem, "Chance of Dyse," written in the early 1400s, contained 56 verses, each being a fortune corresponding to the 56 sets of possible throws of three dice (Bennett 60).

Throughout time, chance mechanisms have been invented for the purpose of seeking divine direction, to avoid dissonance, for removing the influence of human will, skill and intelligence from their play and from serious decision-making opportunities (Bennett 27). Egyptian tomb paintings dating back more than 3,500 years depict forms of gaming devices or the act of "drawing lots" (hence the word "lottery") (Bernstein 12). One gaming board complete with "men" was excavated in the Babylonian city of Ur dating back to 2700 B.C. Another thought to be similar to backgammon was found at the Palace of Knossos in Crete dating to the Minoan civilization (2400-2100 B.C.) (Bennett 17).

Greek and Roman games of chance were played with four-sided astragali or "bones," a term that has persisted over the centuries. Greek vases show men tossing the bones into a circle (Bernstein 13). The Greek word for die is "kubos," derived from the Talmudic word for dice (kubys) and, thus, the English word, "cube" (Bennett 20). The game of craps is

derived from various dice games brought to Europe via the Crusades. Those games were generally referred to as "hazard" from "al zahr," the Arabic word for dice (Bernstein 13). Widely consulted to this day by the Chinese, the *I Ching* (*Book of Changes* from fifth or sixth century B.C.) began as an oracle involving instruments of chance (Bennett 36). Methods to ensure the randomness of a lottery are mentioned as far back as Homer's *The Iliad* (circa 850 B.C.).

A standard form of punishment applied in the Roman army to soldiers guilty of mutiny, cowardice or other crimes involved having one of every 10 soldiers selected by lot, then executed. From this practice comes the word "decimate," from the Latin "decimare," which means to take one in 10 [Gould(b) 47]. In 731 A.D., Jewish defenders of Masada drew lots to determine who would carry out the mass suicide (Bennett 34). In Biblical times, resorting to chance was an accepted way of making decisions. The Old Testament contains several references to chance and casting of lots (Proverbs 18:18; Proverbs 16:33; Jonah 1:7). "*I returned, and saw under the sun, that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favor to men of skill; but time and chance happen to them all*" (Ecclesiastes 9:11).

It was not until after the Dark Ages that serious scientific investigation attempted to understand and control chance. The catalyst remained gambling and games of chance. Girolamo Cardano (1501-1576) was a world-renowned physician, expert mathematician, notable astrologer and accomplished gambler. A prolific writer, his most influential work was *Liber de Ludo Aleae* (*The Book of Games*), which was published after his death. This book laid the foundation on which scientists and mathematicians such as Laplace, Pascal, Fermat, Bernoulli and Fourier would build the Laws of Probability (Bernstein 47; Ruelle 5).

In 1711, Abraham de Moivre published *De Mensura Sortis* (*On the Measure of Lots*), probably the first work that explicitly defines risk as "the chance for loss" (Bernstein 126). Building on these foundations, Jules Henri Poincare (1854-1912), in *Science & Method*, devoted an entire chapter to defining chance and what is meant when one says that an event was due to chance. Poincare formulated the concept of "sensitive dependence on initial conditions"—a concept that is central to the understanding of chaos, meteorology (the "Butterfly

Effect") and, ultimately, to chance (Poincare 67; Gleick 253; Stewart 130).

Poincare also noted that what people call chance arises from a lack of control; he concluded that many situations occur where a very small cause, perhaps an indiscernible difference in the initial state of a physical system that escapes notice, determines a considerable effect which will have momentous consequences that people cannot fail to see at some future point. "We then say that the effect is due to chance" (Poincare; Ruelle 48, 176). If any error occurs in the initial condition, the long-term behavior of the system is random, unpredictable and chaotic—in other words, a time evolution with sensitive dependence on initial conditions (Ruelle 30; Stewart 284). As Louis Pasteur said, "In the field of observation, chance favors only the prepared mind."

Therefore, if it is impossible to know all the initial (causal) data with perfect precision, it is likewise impossible to predict with certainty how the behavior of a system—be it a business, the weather, the lottery, the stock market or a worker in a task/machine setting—will behave or how a sequence of events will play out. This point is further reinforced by Heisenberg's uncertainty principle, which states that everything measurable is subject to truly random fluctuations (Hall 215).

In all sciences dependent on observation—including the SH&E profession—a constant burden is reckoning with errors and uncertainty due to imperfections of human senses, information processing, physiology, etc., and the instruments employed to measure and control the environment. To mirror Pasteur's words, in the SH&E field, chance makes a victim of the unprepared mind.

Nearing the Journey's End

A dusty paperback purchased by chance many years ago helped pull together the myriad loose ends leading to a definition. In it, Rastrigin illustrated chance through a simple cause/effect model applied to an equally simple task of ringing a doorbell. A person comes to the door with the intent of summoning the person who resides inside. The act (motion with intent) of pressing the doorbell (input) will, by chance, result in the desired effect: the door opens (outcome).

Whether someone responds or not is a behavior triggered by the initial act or antecedent. Feedback comes from someone in the house hearing the bell ring. Certainty comes from the door opening and the desired person greeting the visitor.

In this example, "energy" and the transmission of information flow through one or more paths to an uncertain outcome. This uncertainty is inescapable, as one or more of the following causes might exist:

- The doorbell might not work.
- Power to the doorbell's circuit may be disconnected.
- The in-house chime might not be working.
- The person may not be home to hear the chime.
- The person may not want or be able to answer the door.

This example contains several foundational constructs to defining chance: a) personal action or motion through which b) energy or information flows along c) paths intersecting with or confronting d) controls, barriers or resistance, e) raising uncertainty with respect to input and outcome, eventually f) confronting the often unpredictable human dimension of choice or free will to respond (feedback).

The Journey Ends: A Definition

Throughout this journey, bits and pieces of a definition slowly began to coalesce. What follows is a synthesis of all that was experienced along the way, culminating in what is a personal perspective on chance, how it relates to the SH&E profession and to Hazrin prevention or control. Only the most relevant pieces of the puzzle are set in place to reveal a workable definition.

•First, quantum mechanics offers the construct of "phase space"—a multidimensional domain within which the position of an atomic particle can be determined (Ruelle 111).

•From physics and mathematics comes the term "probability cloud"—a loosely defined term referring to the probability distributions that specify the likelihood of finding an electron in various regions circling about the nucleus (Gamow 118). The particle has mass, energy and position as it moves about that space. The probability cloud is densest where there is a higher probability of finding the particle.

•From the combination of these terms is drawn an analogous term, "causal space"—that domain which surrounds any and all "things" in a human/machine interactive macroenvironment through which chance can act. For example, a worker wearing protective equipment is at the controls of a powered vehicle driven within a factory in which other workers, machines and powered vehicles operate.

•"Energy," or potential difference, is

the next piece, expressed parenthetically to imply the broadest scope of that term. It embraces all possible forms of energy or motion, such as kinetic (e.g., powered vehicle in motion) or potential (tank of LP gas), and traditional forms such as mechanical, electrical and chemical. Also included are nontraditional or abstract energy forms such as curiosity, free will, intent, creativity, knowledge and those chance-favored personality types (Table 1).

•Paths are needed through which energy may flow within the causal space—paths that are serial, parallel or intersecting (recall Kamen's "spaghetti bowl of paths" or the doorbell circuitry). Within the bounds of that causal space, paths may be more concentrated (denser with respect to both space and time, i.e., greater probability) in one area compared to another. The causal space "boundary" or perimeter is where the paths terminate in any number of potential points of contact or interaction.

•Finally, one or more additional causal spaces are needed to intersect or contact with the original, again, in space and time (vehicle collides with another).

The question repeatedly confronted during this journey was, "Does chance exist?" Purely a personal conclusion, it would seem that chance is an abstraction—that it does not exist except when the above conditions exist. That is:

•There must be multiple causal spaces.

•One or more of those spaces must be in motion.

•Possible paths through which energy can flow must be present (Johnson 228).

•More or denser concentration of paths and/or points of contact will exist within the causal spaces (greater probability of points of contact).

•Energy must be present and be able to flow (a potential difference).

•The path or paths through which the energy(ies) flows between or among the intersecting causal spaces is not controlled or is inadequately controlled.

•Feedback loops or communication mechanisms exist, as does an imbalance, a potential difference (i.e., competition) between or among those feedback loops (positive or negative) (Briggs and Peat 40, 84; Johnson 154).

•Causal spaces must intersect, leading to an uncertain or unexpected (possible) outcome(s).

The result of all of these elements is a chance-outcome. In addition, the severity of that outcome is itself chance-dependent. Flowing energy must have made con-

tact with the boundary of another causal space (e.g., a person's body or a physical structure). It must connect with a path(s) at the boundary of the other causal space. Furthermore, it must do so in such a manner or with sufficient magnitude for the energy to exceed the threshold limit or tolerance of that other causal space (i.e., the person or structure) at the point of contact(s). Finally, reflecting on those points and all that was experienced, the journey ends with this definition: "Chance is that abstract nature of causation subscribing all possible uncontrolled paths through which energy flows in uncertain ways to all possible outcomes."

In its simplest form, chance is a path to an uncertain outcome. It is what potentially remains to occur after acceptable risk or control is reached. No matter how hard people try to eliminate or control chance, it will always, given enough time, find an obscure or uncontrolled path, sneak around a barricade or take advantage of chance-conducive personality traits when given the opportunity. Acknowledging that there are limits to people's ability to anticipate, identify, measure or control is fundamental to risk-taking. As Poincare states, there will always be "situations where a very small cause . . . escapes our notice, [and] determines a considerable effect that will have momentous consequences. . . ." Yet people persevere. It is what makes people human.

Meaning for the SH&E Professional

It seems fitting to end this journey where it started, with a question, "What does all this mean for the SH&E professional?" Perspectives gained along these travels were sufficiently convincing that the true essence of safety management lies in achieving a state of acceptable control. This can be accomplished by:

- Identifying and maximizing opportunities where it is possible to achieve or exercise acceptable control, and anticipating and minimizing those opportunities where limited or no control exists.
- Ensuring feedback loops and the adequacy of information content and flow from source to recipient and back. In other words, the SH&E professional must minimize uncertainty where the link between cause and effect is hidden from view.

Despite the everpresence of chance, multiple opportunities exist to prevent Hazrins. The SH&E professional has the ability and responsibility to influence the:

- design of acceptably safe, human-centered, systems;

- control of energy at its source or at the point of contact with the body or structure;

- elimination or blocking of causal paths through which unwanted (wasted) energy can travel or be released (Haddon; Manuele 239);

- strengthening of points of contact between intersecting causal spaces (e.g., guards or PPE);

- transfer of information—i.e., communication via positive and/or negative reinforcing feedback such as by measuring and evaluating performance against standards or goals;

- shaping of individual/business cultural traits and processes by setting standards and expectations;

- education of business managers regarding what safety is and how it should be managed;

- alignment of SH&E goals with business objectives;

- mitigation of adverse impacts from hazard-related events once they occur.

The SH&E professional must also develop a systems view of the organization. S/he must understand its culture, business environment, processes, interaction of subsystems through feedback loops, and what it reinforces, either through positive or negative feedback.

This and more can be accomplished with greater certainty when built on a solid foundation in safety and risk. Defining and understanding chance and its role in the causation of Hazrins is one cornerstone of that foundation. This travelogue has concluded with its destination reached. But is the journey over? Perhaps, by chance, it opens another door to another path to a more certain outcome. May the questions, the journey, the discovery continue. ■

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