A Systematic Approach to Improve School Safety

Meghan Carmody-Bubb
Our Lady of the Lake University

ABSTRACT

The article examines the application of human factors and systems engineering models to the issue of school safety. While human factors and systems engineering models have been applied to a variety of complex organizational systems to improve safety, the same cannot be said of schools, even though schools meet the same criteria of complex adaptive systems that characterize many organizations. In this article, systems safety research is reviewed, focusing on two specific tools from human factors/systems engineering that have been applied to safety within complex adaptive systems: Human Factors Analysis and Classification System (HFACS; Wiegmann & Shappell, 2003) and the Cynefin Framework (Snowden & Boone, 2007). The state of school safety is reviewed and an argument made for why schools should be addressed as complex adaptive systems.

Keywords: systems engineering, school safety, complex adaptive systems, human factors

INTRODUCTION

There is an expectation of safety when children and young adults are sent to school, but recent research indicates we are naive in that assumption. While, indeed, instances of school shootings are rare, many more are likely thwarted before they ever make the news. A review of the literature indicates violence in schools is at alarming levels (Eden, 2017). A report from the Centers for Disease Control (Department of Health and Human Service/CDC, 2016) calls the level of violence in schools unacceptable. The report indicates that, nationwide, 22.4% of students had been in a physical fight at least once within the year prior to the survey. Six percent of students had been threatened or injured with a weapon one or more times on school property. Approximately 20% of students reported having been bullied at least once in the previous year on school property. Additionally, 17.7% of students had seriously considered suicide in the year prior to the survey, and 8.6% had attempted suicide.

Victims of violence are not limited to students. According to a report by Max Eden, a senior fellow at The Manhattan Institute, the majority of teachers in surveyed school districts across the country reported severe discipline problems that affect their health and safety and disrupt the learning environment (2017). The American Psychological Association also reports violence against teachers has reached epidemic proportions. An anonymous web based survey of nearly 3000 teachers found that 80% reported at least one victimization experience in the current or past year, with 94% of those reporting victimization by students (Espelage, Anderman, Brown, Jones, Lane, McMahon, Reddy, & Reynolds, 2013; apa.org/monitor/2013/11/ce-corner.aspx). The APA also reports, in a document entitled, *A Silent National Crisis: Violence Against Teachers* (2016), that, according to the U.S. Department of Education (2015), from 2011 to 2012 approximately 20% of public school teachers reported being verbally abused, 10% reported being physically threatened, and 5% reported being physically attacked in schools (https://www.apa.org/education/k12/teacher-victimization.pdf).

These statistics demonstrate a crisis of public health, both mental and physical. Jayasinghe (2011) defined population health as "'the health outcomes of a group of individuals, including the distribution of such outcomes within the group'. The approach in population health is to improve the health of an entire population and goes beyond the individual focus in medicine or preventive health" (p. 1).

SCHOOLS AS COMPLEX ADAPTIVE SYSTEMS

Jayasinghe (2011) further argues the classic approach to health promotion and prevention is derived from the Newtonian approach to science, which has three components: reductionism, linearity and hierarchy. According to Jayasinghe, "these ideas appear to have influenced social scientists and the discourse on population health" (p. 1). Jayasinghe further argues that, while these paradigms can predict classical systems of mechanics, they fall short in predicting more complex, nonlinear systems, where simple cause-effect relationships do not necessarily exist. "In contrast, Complexity Science takes a more holistic view of systems. It views natural systems as being 'open', with fuzzy borders, constantly adapting to cope with pressures from the environment. These are called Complex Adaptive Systems (CAS)." (p. 1).

Any school or school district can be described and analyzed as a complex system. A complex system has been defined as possessing several distinct characteristics, including "a large number of interacting elements" in which relationships are nonlinear and dynamic (Snowden & Boone, 2007), which increases the impact and decreases the predictability of events.

PURPOSE OF THE PRESENT PAPER

One could argue the primary goals of any complex man-made system are to safely, efficiently and effectively produce the outcomes said system is designed to produce. For education, these outcomes are students who meet at least minimum standards set by the state for academic outcomes. Additionally, there is an implicit, and sometimes explicitly stated, goal for school districts to also set expectations regarding preparation for a basic level of participation in citizenship.

When an incident of violence occurs at school, be it a fight or an attack on a teacher or fellow classmate, or the comparatively rare event of a school shooting, an error has undoubtedly occurred in the system. This is a system that, like many systems, involves the complexities of human behavior and decision-making. Therefore, the goal of the present paper is to introduce to the topic of school safety concepts and models from systems safety engineering and human factors that have been successfully applied in a variety of complex adaptive systems.

WHAT ARE COMPLEX ADAPTIVE SYSTEMS?

Rather than approaching problems as if all have clear and direct cause-effect relationships, complexity science focuses on those problems that involve interacting, multi-variate factors that must "constantly adapt to cope with pressures from the environment" (Jayasinghe, 2011, p. 1).

SYSTEMATIC APPROACHES TO SAFETY, BASED ON COMPLEXITY SCIENCE

The focus of the present paper is on two potential tools: Human Factors Analysis and Classification System (HFACS) (Wiegmann & Shappell, 2003; 2017), useful in the identification of potential pitfalls in complex adaptive systems, and Cynefin, a decision-making strategy useful in the identification, management and facilitation of decision making strategies (Snowden & Boone, 2007).

A BRIEF HISTORY OF SYSTEMS SAFETY RESEARCH

Most complex organizations have guidelines and checks in place to ensure the overall goals of the organization are met with minimum interference from serious flaws. Examples of such flaws in classic systems engineering applications would be maintenance error in an airplane engine, delivery of the wrong amount of medicine in a medical situation, or a product deficiency. Most complex systems have some sort of quality control in place, particularly when incidents can potentially lead to injury or death. Such guidelines and checks are the result of decades of research into the causes, particularly the precursors, of human error in complex systems.

One of the seminal researchers within the history of both human factors and systems engineering was Edwards, who developed a conceptual model known as the SHEL in 1972 (Wiener & Nagel, 1988). SHEL is an acronym for the components, which involve Software (customs, practices, laws, etc.), Hardware (equipment, etc.), the Environment, and Liveware, the human factor. A key element to a systems engineering approach is a firm understanding that "any change within a SHEL system may have far-reaching repercussions. Unless all such potential effects of change are properly pursued, it is possible for a comparatively small modification in a system component to lead to highly undesirable and dangerous consequences [and] continuous review of a dynamic system is necessary to adjust for changes beyond the control of the system designers and managers" (Wiener & Nagel, 1988, p. 17).

While the tendency with any disaster, including school shootings, is to focus on the immediate action involved in the disastrous event, whether that be the pilot who made the final error in an aviation disaster or the shooter and/or weapon in a school shooting event, years of research into human behavior and human decision making within organizational systems have indicated that seemingly small flaws in a system are often harbingers of deeper underlying issues, and typically precede more disastrous events. "Disaster researchers concluded long ago that disasters cannot be conceptualized except in terms of social, as well as technological or environmental agents (Dynes, 1970; 1970; Quarantelli & Dynes, 1977)" (Short & Rosa, 1998, p. 94). Within classic systems safety research, it is understood that large-scale disasters are nearly inevitably preceded by more subtle precursors, such as minor procedural mistakes, lack of adherence to safety precautions or other organizational cultural guidelines designed to enhance safety and performance (Wiegmann & Shappell, 2003; 2017). The period between mounting precursors and a larger disaster is often known as the Turner Disaster Incubation Period (Turner, 1976). It has precedent in associations illustrated by previous researchers, including in the metaphors of the domino effect and accident pyramid (Heinrich, 1941), which illustrate how incidents build one upon the other, and how the final grand system failure that is disastrous is only the "tip of the iceberg", masking larger problems and an overall systemic failure beneath the surface.

The critical element Turner (1976) added to the risk management equation, according to Short and Rosa (1998), was the focus on the social and cognitive elements that precede a disaster, often for long periods of time. Turner (1976) and Turner and Pidgeon (1997) brought to light "the nature of important organizational and cognitive patterns that contribute to risk, both of which tend to be ignored in risk assessments: blind spots in organizational cultures concerning hazards; inadequate information; poor communication; the masking of error in large and complex organizations; and failure to comply with safety regulations (deliberate or inadvertent)" (Short & Rosa, 1998, p. 95). According to Turner (1976), "Common causal features are rigidities in institutional beliefs, distracting decoy phenomena, neglect of outside complaints, multiple information-handling difficulties, exacerbation of the hazards by strangers, failure to comply with regulations, and a tendency to minimize the emergent danger" (p. 378). The underlying link to many of these preceding events involves breakdowns in management and leadership (Wiegmann & Shappell, 2003; 2017).

APPLYING SYSTEMS ENGINEERING TO SCHOOL SAFETY

Unfortunately, we may have reached levels of potential for injury and death in schools that warrant this same attention to "quality control" and checks for flaws in the system – the proverbial "red flags".

Red flags are a colloquial term for latent failures, first introduced by Reason in 1990 to address the issue of monitoring and correcting potential safety flaws within aviation systems. According to Reason, "latent failures are present long before an accident and hence are prime candidates for principled risk management" but a key element that has been applied to non-aviation environments is the "shifting of intervention target areas from active errors to latent conditions" (Berry, Stringfellow, & Shappell, 2010). A particularly important contribution of Reason (1995) to the study of human error in organizations was the idea "decisions made in the upper echelons of an organization create the conditions in a workplace that subsequently promote individual errors and violations" (pg. 88).

What are the red flags in school safety, including incidents of shootings? What is being missed? In prominent cases that have made national news, such as Columbine, Sandy Hook and Marjorie-Stoneman Douglass in Florida, there were red flags for many years (Kohn, 2001; Shortell, 2014; CBS News, 2018).

While large scale shootings that make the news may be rare, it bears repeating that recent studies have indicated that serious incidents of violence, to include bodily harm, are indeed quite prevalent (Espelage et al., 2013; https://www.apa.org/education/k12/teacher-victimization.pdf). But even the smaller and more frequent incidents – i.e., latent errors in the system, are not factors that should be ignored.

The Systematic Approach to Human Error in Complex Systems Is Expanding

More recently, systems engineering principals focusing on latent errors within complex systems have been applied in areas as seemingly diverse as biopharmaceutical manufacturing (Cintron, 2015), medical practice (Braithwaite, 2018; Neuhaus, Huck, Hofmann, St Pierre, Weigand, & Lichtenstern, 2018), military training (Hastings, 2019), innovation (Zhang, Yi, & Zeng, 2019), and cybersecurity (Kraemer & Carayon, 2007; Mitnick & Simon, 2003; Lier, 2013a; 2013b; 2015; 2018; Barnier & Kale, 2020). Such applications demonstrate why the work of researchers such as Reason (1995) and Rasmussen (1982) continue to be relevant today, expanding into fields outside of which they were originally developed.

The common link in all these situations is that they involve human behavior and human error within complex systems.

Specific Tools from Systems Engineering Applied to Complex Adaptive Systems: Human Factors Analysis and Classification System

Reason's (1990; 1995) concept of addressing latent errors before they become active was later expanded by Wiegmann and Shappell (2003; 2017) into a system that could be applied to the analysis of human error in aviation systems through the Human Factors Analysis and Classification System (HFACS), which is displayed graphically in Figure 1 (Appendix).

The Human Factors Analysis and Classification System (HFACS) was originally developed for the purpose of analyzing human factors contributing to aviation accidents. It provides a framework for the classification of human error within complex organizational systems. The goal is to provide a systematic tool for analyzing latent and active errors to facilitate awareness training, policy development, and prevention of future disasters. The methodology seeks to discover the origins of active errors by focusing on latent errors within four organizational levels. The idea is that, coinciding with the classic domino effect metaphor (Heinrich, 1941), if at least one latent error (domino) is removed, the chain of errors will be broken and the disaster will not occur.

It is important to note that, while used in accident investigation, the tool can also be used as a hypothetical to examine potential weaknesses in any organizational system. Fu, Cao, Zhou, and Xiang (2017) argue the model can be implemented in many areas, as it is based on the seminal safety theories of Reason (1990), which they indicate "continues to be one of the most widely cited and respected works in the field of behavior safety" (p. 571).

It is also important to note at this point that, while it may appear HFACS takes a somewhat reductionist approach, based on Jayasinghe's (2011) description, by "identifying, describing and analyzing all constituent parts" (p. 1), it does not presume linearity, in which "the overall output is a summation of the constituent parts" (p. 1). Within HFACS, the organizational elements are viewed as and interacting within a system involving the complexities of human behavior. For a reprint of the Human Factors and Analysis Classification System, see Figure 1 (Appendix).

The true usefulness of the tool, within this context, addresses a core concept indicated by both Kopsch and Fox (2016) and Raisio, Puustinen, and Jantti (2020). It is "important to not only identify the right problem, but also to be aware of the type of the identified problem and its possible connection to other problems" (Raisio et al, 2020, p. 5).

At the lowest level of the HFACS framework, Level I, there are the latent errors most directly linked to the eventual active error (accident/disaster). This level is known as *Unsafe Acts of Operators*. It is divided into two categories of unsafe acts: Errors and Violations. Errors are unintentional and are further divided into errors based on faulty decision making, lack or misapplication of skill, or misperceptions of available information. Violations, on the other hand, involve willful disregard for rules and procedures. They are categorized as routine (meaning they regularly occur within the organizational system) and exceptional (out of the norm). Within the context of school safety, examples of errors at Level I within the system could include failure on the part of resource officers or teachers to recognize a potential threat at the time of the incident (i.e., missing a suspicious student concealing a weapon and entering a building).

Examples of violations at Level I could range from routine disregard for identification and sign-in procedures or the locking of doors, to the deliberate failure of a resource officer to intercede a suspect.

Level II of the HFACS classification framework examines *Preconditions for Unsafe Acts*. This is where the system really begins to analyze underlying latent errors. Such preconditions are divided into Substandard Conditions of Operators and Substandard Practices of Operators. Here, the building complexity of applying HFACS to any system, particularly school safety, becomes more obvious. The conceptual definition of "operator" must broaden to include evaluations of both the individual(s) directly responsible for a disastrous act (i.e., the school shooter) and the operator(s) who may be directly responsible for preventing the act. Moreover, in contrast to the original applications of HFACS to aviation safety, the goals of operators in the case of a school shooting are competing, rather than cooperative. Substandard conditions can be applied to both, but the origins, as well as the solutions, may be very different when evaluating the behaviors of the school shooter as operator versus, say, the resource officer. In the former case, one may likely be dealing with mental health issues; whereas in the latter, one may be dealing with issues such as overwork or fatigue. Likewise, within the category of Substandard Practices, in the case of the school shooter, issues may revolve more along the lines of failures to appropriately monitor internet communications and coordination of potential school shooters or inadequate counseling, behavioral and/or medical interventions (Personal Readiness), whereas in the case of the resource officer or teacher who fails to recognize or stop a potential shooter, one could be dealing with lack of communication and coordination on the part of the school (CRM, or Crew Resource Management) or failure to adhere to physical or job training requirements on the part of the teacher or resource officer.

Level III of the HFACS classification framework is labeled Unsafe Supervision, and this is the level at which the underlying culture and leadership within the organization comes into play. This level is divided into 4 categories: Inadequate Supervision, Planned Inappropriate Operations, Failed to Correct Problem, and Supervisory Violation.

In the case of Unsafe Supervision, as applied to school safety, this could involve administrators who fail to incentivize proper training and procedures. The author of the present paper would further argue that failure on the part of administrators to enforce a disciplined and orderly school environment would also fall within the category. One could further argue the category of Failure to Correct Known Problems has been particularly relevant within the context of school shootings, as reports from schools such as Columbine, Sandy Hook, and Stoneman Douglass (Kohn, 2001; Shortell, 2014; CBS News, 2018) indicate red flags were ignored or inadequately addressed for long periods of time. Complicating this is the category of Supervisory Violation, in which administrators may arguably misinterpret or misapply FERPA laws (Federal Educational and Privacy Act, 1974) within the elementary and secondary school levels and fail to report potentially dangerous students to police officers, or to make community stakeholders (parents and school taxpayers) aware of potential safety issues within local schools.

Finally, the highest level of HFACS, *Organizational Influences*, addresses the top tier of leadership within any organization. Again, this may be complicated in the school setting, as leadership may involve different levels of administrative, community, and governmental bodies. However, as with the original application, this is not an untenable task. The focus at this level tends to be on the top leadership within an organizational structure and how it works within existing laws and constraints, rather than addressing issues at a governmental or legislative level. As applied to school safety, this level would then apply to the Principal of a particular school, or the Superintendent of a District, depending on the particular issue. It may also involve the leadership of the law enforcement body of the school.

ORGANIZATIONAL CULTURE AND THE APPLICATION OF HFACS

HFACS has been applied in many areas outside of aviation, including medicine (Neuhaus, Huck, Hofmann, St Pierre, Weigand, & Lichtenstern, 2018), rail line safety (Madigan, Golightly, Madders, 2016), the Oil and Gas industry (Theophilus, Esenowo, Arewa, Ifelebuegu, Nnadi, & Mbanaso, 2017) and cybersecurity (Pollack, 2017). It has proven to be a useful tool for identifying latent, as well as active, errors within complex systems, and data support its effectiveness in reducing errors and accidents, and thereby enhancing safety. There is no reason to believe it would not be equally effective when applied to the problem of school safety.

However, tools such as HFACS are only effective if properly implemented. This can be particularly challenging in socio-cultural complex systems.

Creating an Organizational Culture that Supports Learning

It is important to remember that a CAS system is, by definition, adaptive, and hence has the capacity to change by learning and responding to even small changes within the system (Snowden & Boone, 2007). This is paramount to establishing what Rahim (2015) has called a learning culture/organization and setting what Westrum and Adamski (1999) described as an organizational culture that promotes safety. Such a culture was originally defined by Pidgeon and O'Leary (1994) as "the set of beliefs, norms, attitudes, roles and social and technical practices within an organization which are concerned with minimizing the exposure of individuals, both within and outside an organization, to conditions considered to be dangerous (p. 32)"

Westrum and Adamski (1999) argued that "the critical feature of organizational culture for safety is information flow" (p. 83). Based on an earlier work by Westrum (1993), there are three climates for information flow: pathological, bureaucratic and generative. While bureaucratic organizations can contribute to latent failures, latent failures reach their peak in a pathological organizational climate, in which anomalies are handled "by using suppression or encapsulation. The person who spots a problem is silenced or driven into a corner. This does not make the problem go away, just the message about it. Such organizations constantly generate 'latent pathogens'" (p. 84). The pathological organization is further characterized by information being hidden, responsibilities shirked, failures covered up, and new ideas crushed (Westrum & Adamski, 1999). Westrum and Adamski further indicate that the pathological organization is "dangerous where it exists" (p. 84).

More recently, Roberto (2013) argues the culture of the organization impacts the flow of information and can contribute to or inhibit problem solving. In his book, *Why Great Leaders Don't Take Yes for An Answer*, he contrasts the Bay of Pigs and Cuban Missile Crises to dramatically illustrate how the organizational culture set up by a leader can impact the flow of information, contributing to the success of overall decision making in crisis and/or strategic situations.

The Leader's Role in Decision Making within Complex Adaptive Systems

In fact, the management of information flow is arguably one of the most important factors in framing strategic decision-making. Raisio, Puustinen and Jantti (2020) postulate that "a complexity-aware leader ought to be able to separate routine management issues from the more complex variants" (p. 5). A recent approach to framing decision situations, to include complex adaptive and disordered systems, is Cynefin (Snowden & Boone, 2007). While the full text of the Cynefin framework is beyond the scope of this paper, much of it centers on how leaders must handle the flow of information, and how the task of decision-making changes depending on the situation, as well as the certainty of the available data and information. It is a method that was specifically designed for use in complex adaptive systems, and it systematically classifies decision contexts so that leaders can recognize their job in guiding the decision process, the danger signals indicating a poor process that may lead to cognitive bias and errors, and how to respond to those dangers. According to Van Beurden, Kia, Zask, Dietrich and Rose (2013), tools derived from complexity science, such as the Cynefin framework, "provide a lens through which we can better understand multi-causal dynamics within our contexts, issues, organizations, and communities" (pp. 75-76).

The Cynefin framework (Snowden & Boone, 2007) is divided into ordered systems (comprised of simple and complex), unordered systems (comprised of complicated and chaotic) and disordered systems, the latter of which cannot be readily classified, and require a "wait and see" approach. Within the framework, simple systems are characterized by relative stability and clear cause-effect relationships. The leader's role is to assess facts, categorize them, and respond with "best practice". In complicated systems, cause-effect may not be as clear and analysis involves greater expertise. As there may be multiple solutions and opportunities for creativity, this is characterized as the domain of "good practice". Whereas the ordered systems, simple and complicated, are argued to demand "fact-based management", the unordered systems, complicated and chaotic, are described as requiring "pattern-based leadership". Within the complex domain, at least one solution is available, but not readily found. The environment is more dynamic, but still involving unknown unknowns. The leader's primary role is to probe for information and search for emerging patterns, and there is a need for creative and innovative approaches, and a call for pattern-based leadership. Finally, within the chaotic domain, constantly shifting variables make cause-effect patterns extremely difficult to detect in real-time. The goal of the leader is to act first to get the situation under control so that the situation can shift to complex (Snowden & Boone, 2007).

APPLYING CYNEFIN FRAMEWORK TO SCHOOL SAFETY

According to Sardone and Wong (2010), "Traditional management techniques have been developed to deal with Ordered systems… Safety issues reside in the Complex domain and therefore should not be addressed by relying solely on techniques developed for Ordered systems, namely best practices or expert models." (p. 4)

There is a strong argument to be made that, indeed, worrisome safety issues often reside in the Complex domain, and this is true in the case of school safety. In the taxonomy of the Cynefin framework, the focus solely on gun measures is an example of applying measures appropriate to a simple domain (sense what happened, categorize it, and respond to it) to an issue that falls more in line with the complex domain. It involves many interacting socio-cultural elements at the level of family, community, and governmental structures. Within the complex domain, the appropriate first response is to probe – search for emerging patterns and seek input from stakeholders at multiple levels in order to collaborate on potential solutions (Snowden & Boone, 2007). Appropriate gun measures may well be one potential solution at one level of the system, but this approach alone fails to address the underlying socio-cultural issues that lead to the need to address access to guns in the first place. Authors van Beurden et al. (2013) argue tools derived from complexity science, such as the Cynefin framework, "provide a lens through which we can better understand multi-causal dynamics within our contexts, issues, organizations, and communities" (pp. 75-76).

LESSONS/APPLICATIONS OF COMPLEXITY SCIENCE TO SCHOOL SAFETY

Conclusion

A fundamental concept established through decades of research into human error is that most errors are the result of misinterpretation and miscommunication of information, with resulting failures in decision making and execution. More importantly, the overall organizational context of the system can be such that it either increases or decreases the likelihood of such errors in processing (e.g., Reason, 1990; Shappell & Weigmann, 1997; 2009). Latent system errors lead to active system errors when left unchecked within the system. We cannot fail to notice the disastrous active errors, but a good organizational culture is one that has, built into the system, a learning culture that facilitates the identification and correction of latent errors before they can lead to larger scale active errors.

While the problem of school safety is complex and daunting, there are models and precedents that have been successfully applied to increase safety in equally complex domains. Two such models have been the focus of the present paper. HFACS (Wiegmann & Shappell, 2003; 2017) allows for a systemic examination of the chain of events that can lead to fundamental systemic failure, and the Cynefin Framework (Snowden & Boone, 2007) provides a systematic tool for leaders and teams to assess the complex socio-environmental factors that frame and define the decision domain, including potential pitfalls and decision-making challenges within that domain. The human factor is the common link. It is time to take a less political and more systematic approach to the problem of school safety.

ACKNOWLEDGEMENTS

Special thanks are due to my colleague, Dr. Jared Montoya, for reading and critically evaluating my paper before submission. Your feedback was timely, thoughtful and tremendously helpful.

Special thanks, as well, to my husband, Michael Bubb, for your painstaking review from the perspective of an engineer and cybersecurity expert.

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APPENDIX

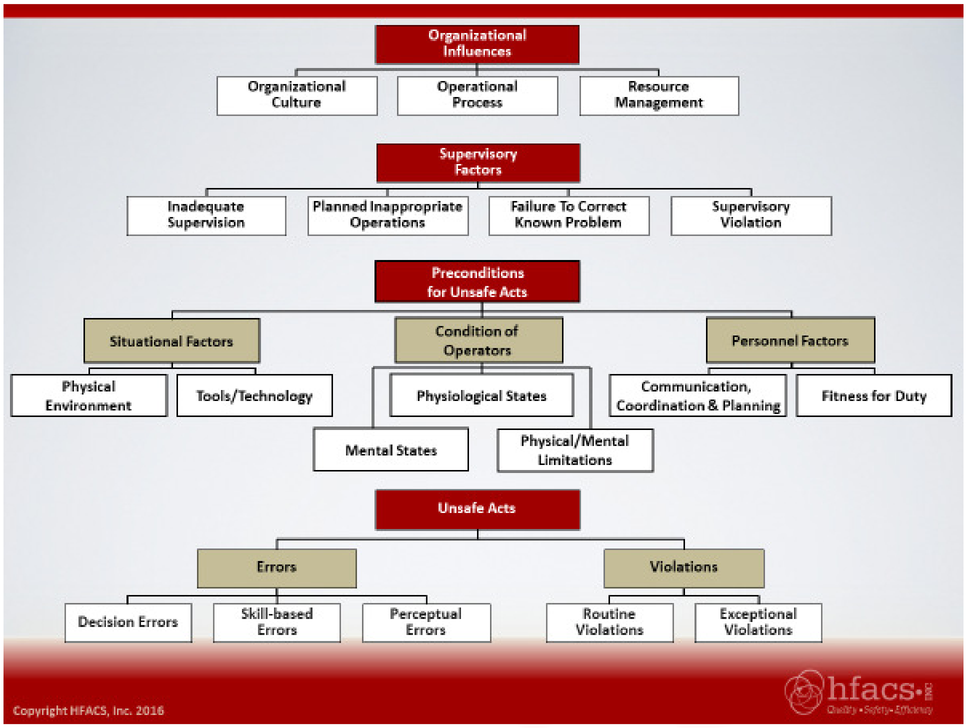

Figure 1. Human Factors Analysis and Classification System (HFACS) *Note*: Reprinted from https://www.hfacs.com/hfacs-framework.html. Copyright HFACS, Inc. (2016) Reprinted with permission.