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Course Learning Outcomes for Unit II

Upon completion of this unit, students should be able to:

4. Discuss system safety related program strategies.
   4.1 Explain how safety is designed into product life cycles and the subsequent relevance of engineering safety into the system life cycle.
   4.2 Discuss the concept of decision science in system safety engineering.
   4.3 Discuss the elements of a properly engineered safety management system (SMS).

Course/Unit Learning Outcomes	Learning Activity
4.1	Assessment, Lesson, Required Reading
4.2	Assessment, Lesson, Required Reading
4.3	Assessment, Lesson, Required Reading

Reading Assignment

Chapter 4: Safety Management Systems

Unit Lesson

One of the most powerful tools that safety engineers can have at their disposal is a conceptual model. As scholar-practitioners of safety engineering, you need to first investigate the rationale behind conceptual models in this field of study, understand the implications underpinning conceptual models as a significant analysis tool for accident causation, and subsequently learn to evaluate and improve conceptual models that you encounter in your work.

Recalling Deming's (1986) plan-do-check-act or PDCA cycle, scholar-practitioners of safety engineering need to embrace the same continuous improvement principles that grew from von Bertalanffy's (1968/1972) general systems theory. This is where we as contemporary scholar-practitioners of safety engineering are called in a different manner from industry's safety managers and traditional safety engineers. We must seek to understand (plan), apply (do), critique (check), and modify (act) traditional and contemporary conceptual models for accident causation.

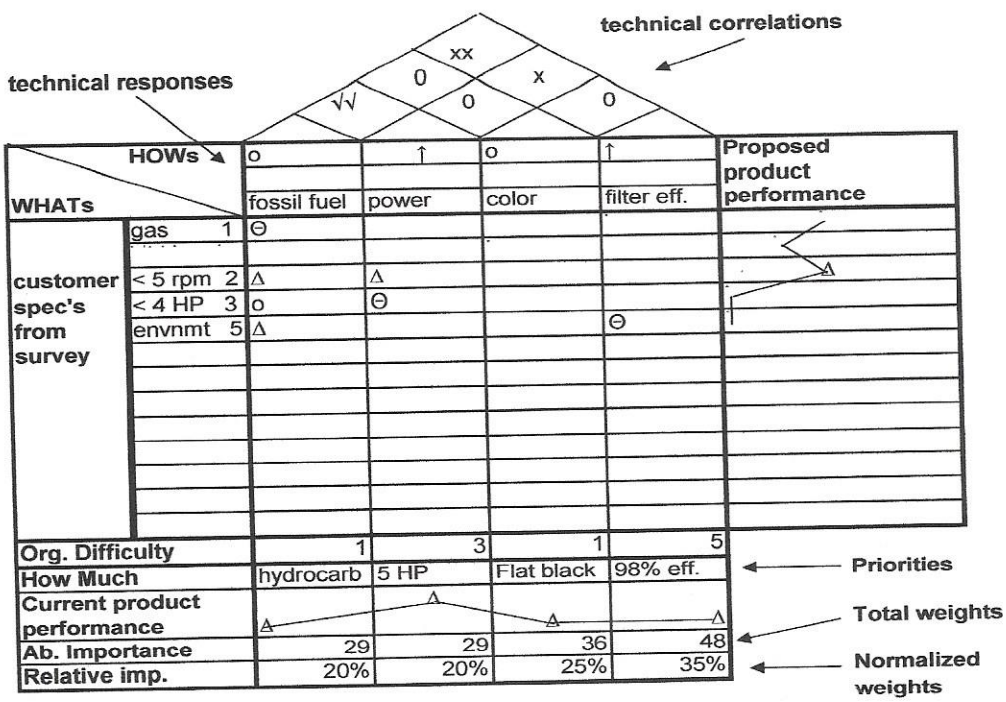
Safety engineers are actually decision management scientists. You devote your time and efforts to a focus on helping others make better decisions to ultimately mitigate accidents involving themselves and the environment. As such, you study work systems to identify and understand the independent variables and causally related hazards to humans and the environment, remove or replace those variables with variables not causally related to accidents, use engineering and administrative controls to engineer out remaining hazards, and then measure the effectiveness and perceived safety of the work system with statistical data analysis before exposing humans or the environment to the work system. This requires strong, linear thinking for strong, linear decision-making, even with multiple and often complex variables.

You may recall that Deming (1986) was adamant about using data-based decision-making in the check stage of the PDCA cycle. Safety engineers need models to fully understand a given work system. Safety engineers insert data into the model to quantitatively evaluate the system and derive options for change or improvement to the system based upon the results. This is applied data-based decision-making.

Modeling a decision often requires formulating a conceptual model, then collecting the relevant data to use in the model. The use of qualitative pictorial models readily helps the safety engineer understand the basic variables within a work system; however, quantitative mathematical models can seem more abstract than pictorial models, as they often incorporate factors that are difficult to visualize. Still, mathematical models provide the level of empiricism required to quantitatively evaluate a work system. As such, some of the most effective models that we can use in safety engineering are arguably hybrid models containing both pictorial structures and quantitative elements (Monks, 1987). As we will soon learn in future units, the life cycle of any product, either tangible products or service deliverable products, is extremely important to consider when designing engineered safety management systems.

One popular conceptual model that contains both qualitative and quantitative features is the house of quality matrix model, derived from a quality process termed quality function deployment (QFD). QFD and the house of quality matrix model were first introduced to United States manufacturers by Don Clausing of Xerox in 1984. Clausing was working in Japan with a Xerox partner and learned about the Japanese industry using a model created by Professor Makabe of the University of Tokyo, Institute of Technology, based on Genichi Taguchi's model and synthesized from their studies on product reliability. Mr. Clausing brought the model back to the United States and shared it with the industry. Later, more intense evaluations of the house of quality matrix model were conducted and used as a predictive tool in product life cycle analysis (Cohen, 1995).

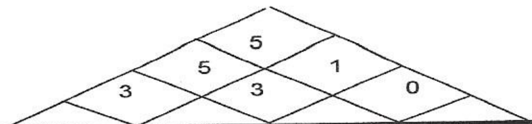
Here is a sample house of quality matrix model for a physical product. In this instance, the QFD technique is being used to evaluate the engineering complexity requirements of designing a small gasoline-powered engine by linking the client's specific requirements for horsepower, color, benefits, and features to the correlated environmental compliance requirements of the project and product. Notice how the measured aspects are all variables within the product's life cycle and have some degree of relevance to some aspects of environmental health and human safety such as hydrocarbon emissions.



Sample house of quality matrix model
(Baumgardner, 2007)

As an example of applied use of QFD as a system safety engineering model, Dr. Paul Baumgardner (2007) developed a modification of the original house of quality matrix model specifically for fieldwork environments with significant hazards that posed threats to humans and the environment.

Baumgardner (2007) designed the first modification to the model specifically to evaluate the effectiveness and safety of the environmental chemical testing of laboratory employees who were to be dispatched to the field to sample and transport air, water, soil, and material samples following spills of potentially hazardous compounds, a service deliverable as the product. The samples would then have to be physically transported back to the laboratory by the employees for chemical analysis and ultimate disposal classification. You will notice the strong use of empiricism in Baumgardner's design, an effort to better quantify risks and forecast performance outcomes as opposed to traditional uses of symbols in the original design. Once again, you will notice that the life cycle of the work system is considered throughout the entire model and is ultimately tied to the overall safety of the work system.



HOWs / WHATs		technology	safety	easy to use	promptness	Proposed product performance
		LIMS	PPE&C	Education	Mobility	
customer spec's from standard survey	tech. 2.5	9/ 22.5		1/ 2.5	3/ 7.5	
	safety 5.0	1/ 5.0	9/ 45.0	5/ 25.0	1/ 5.0	
	ease 1.0	9/ 9.0	3/ 3.0	9/ 9.0		
	prompt4.0	9/ 36.0		1/ 4.0	9/ 36.0	
	info 4.5	9/ 40.5		1/ 4.5	3/ 13.5	
Org. Difficulty		5	3	1	3	
How Much		test data	0 accident	B.S. prof.	24hr./7day	
Current product performance						
Ab. Importance		113.0	48.0	45.0	62.0	
Relative imp.		42%	18%	17%	23%	

House of quality matrix model
(Baumgardner, 2007)

As this example may demonstrate, it is the responsibility of the safety engineer to closely consider models even from different sectors of industry such as the house of quality matrix model from the manufacturing sector as possible candidates for work systems analysis. This means that as scholar-practitioners of safety engineering and decision science, we must become proficient practitioners in the fields of engineering management, engineering development, and operations engineering (also termed operations research and formerly termed industrial engineering). To accomplish this level of proficiency, we must learn to utilize and operate design tools available to industry engineers.

The first part of Chapter 4 discusses how safety is designed into product life cycles and the relevance of engineering safety into the system life cycle. The term cradle to grave is mentioned in this chapter even as it has become synonymous with an organization's perpetual environmental and safety stewardship responsibility. The idea presented is that a comprehensive consideration of potential human and machine failures will help to inform the safety engineer. With this critical information, the safety engineer can then successfully control and ultimately lower associated risks within a given work system (Bahr, 2015).

The four primary parts of a safety management system (SMS) with the appropriate use of a qualitative conceptual model are shown in Figure 4.1 on page 78 in the textbook. You may notice that all four elements have a strong human component to them with the foundations of each being executive management attitudes and actions within an organization. Consequently, you must first closely evaluate and measure the aspects of safety governance, safety organization, system safety program, and safety culture through the lens of two fundamental management tenets: leadership and commitment.

Viewing management as a component of the system safety process necessarily demands that one closely consider the role of industrialization within a society. Herbert Blumer, a noted theorist of industrialization, sought to critically analyze the role of industrialization as a cause of social change. What Blumer (1990) did for our field of study was to make it clear that understanding the interaction of machines with humans, an informal summary of his definition for industrialization, was one of the most critical aspects of understanding the subsequent causal relationships among various industry activities and societal change. Further, Blumer stressed that while the industrial processes introduce situations to a traditional group life order, the actual process can neither explain nor predict how societies will act or react. This is because industry is ultimately controlled by human decisions. Consequently, it can be effectively argued that poor human decisions at the management level can create poor societal outcomes such as workplace hazards or environmental pollution. As such, careful analysis of the decision-making process within a system safety process must begin with executive management commitment to human and environmental safety and effective leadership in managing the system (Leveson, 2011). After you effectively address management aspects, developing a system safety process then becomes an academic exercise of linear thinking, with applied decision-making opportunities embedded within the process system.

The textbook reading finishes with instructions on how to conduct a diagnostic of an organization's SMS health and then provides a detailed description of the system safety program plan (SSPP) that serves to document the SMS for the organization. The SSPP is presented as the key to a healthy, robust SMS. An SMS is only as strong as the SSPP, but the SSPP is only as strong as the corporate governance structure of an organization. This is precisely why we must learn to measure an organization's safety culture as a critical step within the SSPP and then consider the findings of the organization's safety culture as critical values when we ultimately insert them into conceptual models during hazard analysis (discussed in Unit III) and process safety analysis (discussed in Unit IV).

As you carefully review the elements of the SMS SSPP that Bahr presents on pages 97-100 of the textbook, you may start to realize the relative importance of the two-part design of the SMS SSPP, the Safety Management System Program and Policy Administration and the Operational Safety Requirements. The first section, which is most heavily considered, deals with an organization's psyche, while the second section, considered less, deals with the actual operational procedures and requirements of the safety design for the work system (Bahr, 2015).

This unit serves to help you learn the philosophy and relevance of engineering safety into system life cycles within organizations' work systems. This will be critical to understand once you begin using conceptual models to actually engineer controls into work systems during future units of the course. Let your mind really dwell on these concepts before you begin Unit III, and get ready to learn to evaluate the design of properly engineered safety management systems, within the context of this Unit II course work.

References

Bahr, N. J. (2015). *System safety engineering and risk assessment: A practical approach* (2nd ed.). Boca Raton, FL: CRC Press.

Baumgardner, P. (2007). Integrating product development process and quality function deployment for environmental field sampling planning. *Ethics and Critical Thinking Quarterly Journal, 1*(4), 1-55.

Blumer, H. (1990). *Industrialization as an agent of social change: A critical analysis.* Hawthorne, NY: Aldine de Gruyter.

Cohen, L. (1995). *Quality function deployment: How to make QFD work for you.* Reading, MA: Addison-Wesley.

Deming, W. E. (1986). *Out of crisis.* Cambridge, MA: Massachusetts Institute of Technology.

Leveson, N. G. (2011). *Engineering a safer world: Systems thinking applied to safety.* Cambridge, MA: Massachusetts Institute of Technology.

Monks, J. G. (1987). *Operations and management: Theory and problems* (3rd ed.). New York, NY: McGraw-Hill.

von Bertalanffy, L. (1968/1972). *General systems theory: Foundations, developments, applications.* London, United Kingdom: Allen Lane.

Suggested Reading

In order to access the following resources, click the links below

If you did not read this article in the Unit I work as a primer for this Unit II work, you might really benefit from seeing the operationalized demonstration of the author's use of an integrated safety management model that uses a blend of both qualitative and quantitative measurements to better understand safety within the entire life cycle. You will also notice the authors' use of a process flow chart as a conceptual model.

Janaćković, G., Radosavljević, J., Vasović, D., Malenović-Nikolić, J., & Vukadinović, A. (2017). The integrated safety performance model based on safety indicators and safety lifecycle. *Acta Technica Corviniensis-Bulletin of Engineering, 10*(2), 79-82. Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=122599967&site=ehost-live&scope=site

This article is focused on addressing the necessary interaction between the human element of both the management and line worker, as well as the elements within a physically engineered work system. The authors do something unique in that they divide selected elements of a safety management system even to include environmental safety by industry size categories and study the categories by relative performance. This might really help to serve as a solid demonstration of how to first consider management system performance within an internal audit. This article is an excellent example of how social systems must be considered within an engineered safety management system.

Sivaprakash, P., & Joseph, S. (2015). An investigation of safety management elements in small and non-small-scale engineering industries. *Polish Journal of Environmental Studies, 24*(6). Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=110820490&site=ehost-live&scope=site

Learning Activities (Nongraded)

Nongraded Learning Activities are provided to aid students in their course of study. You do not have to submit them. If you have questions, contact your instructor for further guidance and information.

Design a Qualitative Conceptual Model

Select a work system with which you are very familiar such as driving yourself to work in a car. Look at the Figure 2.3 in our textbook as an example. Design a process flow diagram as a conceptual model of your selected work system. Now, consider the junction points between every step. Try to determine at least one hazard that may exist between every step. This exercise will prove to be valuable experience for our system analysis work in future units.