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Course Learning Outcomes for Unit VIII

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

7. Evaluate risk management tools related to system safety management.
   7.1 Discuss the eight-step risk assessment methodology.
   7.2 Discuss how to evaluate risks within a work system.

Course/Unit Learning Outcomes	Learning Activity
7.1	Assessment, Lesson, Required Reading
7.2	Assessment, Lesson, Required Reading

Reading Assignment

Chapter 13: Risk Assessment

Chapter 14: Risk Evaluation

Unit Lesson

In the last unit, you leveraged all of your skills from this class to develop a system safety process plan. You have studied how to identify and engineer out hazards within a work system; however, you have not yet studied how to adequately tie together the risk from the remaining hazards within the engineered work system and evaluate those risk levels. This unit covers how to make a qualitative determination with a quantitative calculation, then relate those quantified risk values to probabilistic estimates of total system failure. It is in this unit that you will now fully account for estimated capital at risk based on the probability of failure occurrences within a work system.

You must remember that at the most fundamental level of safety management lies your inherent responsibility as a safety engineer to effectively communicate organizational risks and available options to executive management. This responsibility is only compounded as you eventually become members of executive management within an organization with or without direct safety engineering or safety management duties. As you use systems theory to defend the notion that a safe work system is a profitable work system, you must learn to communicate that notion in terms of dollars, which is the unit of measurement arguably most meaningful to any organization.

After an informative discussion about what risk really means as it relates to individual perceptions and risk tolerances, the textbook provides you with a risk assessment methodology that accommodates this integrated qualitative and quantitative approach with an eight-step methodology in Chapter 13. This approach serves to normalize many of the frustrating independent variables within a risk assessment that are tied directly to these individual perceptions and risk tolerances and moves you toward risk evaluation in Chapter 14. This is really where you need to eventually be, given that you are ultimately attempting to evaluate and understand the risks inherent within a work system after all controls have been designed into the system, at least during a first cycling through Deming's (1986) plan-do-check-act continuous improvement cycle.

Your textbook, in its discussion on risk evaluation, revisits some information and techniques from Unit IV related specifically to probabilistic mathematics and statistical forecasting of risks; however, the concepts may still be a little too difficult to grasp even at this point in the course. As such, it may be a good time to pause, consider the context of what is provided in both Chapters 13 and 14, and then consider a working example of how you can actually make a qualitative determination. Afterward, you can use those data to calculate a quantitative value for risks. Using some of the same referenced authors from the textbook, let's focus our risk assessment and risk evaluation on the aspect of total risk exposure within a given work system.

Stephans has published a method that will afford us the opportunity to qualitatively determine risk exposure with human perception or perceived severity during risk assessment and then calculate a value for total probabilistic risk exposure. Risk exposure is then used to calculate an actual projected dollar loss per unit, a metric that can be meaningfully tied back to the ratio of exposure to projected costs of controls (Stephans, 2004). Consequently, this technique provides a qualitative determination of risk based on organizational risk tolerances and individual risk perceptions, a quantitative risk evaluation of the work system in terms of dollars, and a correlation of the cost of controls for the engineered work system as a function of the organization's budget.

You may notice how Bahr (2015) bases risk evaluation on two principles, the cut-set probabilities of system failure and the economics management theory equation of expected values. The combination of these two principles allows for a calculated yield of a fairly accurate estimate of safety costs. You can see the yielded outcome of these two utilized principles in Table 14.2 and the risk calculation on page 368. This may not be completely clear at the moment, so let's work through Stephan's techniques as an alternative method.

Stephans (2004) described a severity code table, based on perceived risks. Using this philosophy, we are going to develop our own severity code table (below), but with different, fabricated values, only for the purpose of practicing this technique. This is nothing more than a ten-point Likert scale, but it is tied to both capital and probabilistic cut-set values. Please remember that these are fabricated numbers and are not the same values presented by Stephans (2004).

Severity Code	Range (in dollars of capital)	Average
10	>11 Billion	$5x10^{10}$
9	1.1-11 Billion	$5x10^{9}$
8	101 Million – 1.1 Billion	$5x10^{8}$
7	11-101 Million	$5x10^{7}$
6	1.1-11 Million	$5x10^{6}$
5	101K-1.1 Million	$5x10^{5}$
4	11-101K	$5x10^{4}$
3	1.1-11K	$5x10^{3}$
2	101-1.1K (1,000)	$5x10^{2}$
1	<101	$5x10^{1}$

Stephans then described an exposure code table based on the total number of accidents as lagging or trailing metrics. Once again, we are going to develop our own exposure code table (below) with different, fabricated values solely for the purpose of practicing this technique. The ten-point Likert scale and probabilistic cut-set values are again utilized. This is important, given that we will be tying together these two variables, severity and exposure, to understand total risk exposure to a work system. Please remember that these are fabricated numbers and are not the same values presented by Stephans (2004).

Exposure Code	Range (in number of accidents)	Average
10	>100	$5x10^{2}$
9	10-100	$5x10^{1}$
8	1.0-10	$5x10^{0}$
7	0.1-1.0	$5x10^{1}$
6	0.01-0.1	$5x10^{-2}$
5	.001-0.01	$5x10^{-3}$
4	.0001-.001	$5x10^{-4}$
3	.00001-.0001	$5x10^{-5}$
2	.000001-.00001	$5x10^{-6}$
1	<.000001	$5x10^{-7}$

Finally, Stephans described a total risk exposure code (TREC) matrix. This affords us the opportunity to quantitatively correlate the severity to exposures. We are going to develop our own risk exposure code matrix, using more fabricated values, solely as an example of how to use this method. Realize how we have used only qualitative determinations for establishing severity and exposure, to this point, albeit qualitative determinations based on empirical values. Please remember that these are fabricated numbers and are not the same values presented by Stephans (2004).

					Exposure	Code					
		10	9	8	7	6	5	4	3	2	1
	10	20	19	18	17	16	15	14	13	12	11
	9	19	18	17	16	15	14	13	12	11	10
	8	18	17	16	15	14	13	12	11	10	9
Severity	7	17	16	15	14	13	12	11	10	9	8
Code	6	16	15	14	13	12	11	10	9	8	7
	5	15	14	13	12	11	10	9	8	7	6
	4	14	13	12	11	10	9	8	7	6	5
	3	13	12	11	10	9	8	7	6	5	4
	2	12	11	10	9	8	7	6	5	4	3
	1	11	10	9	8	7	6	5	4	3	2

Now, we can do some simple calculations to derive the following four estimates using Stephan's suggestions.

1. Total risk exposure (TRE) = $5 \times 10^{(TREC-5)}$ or the total dollars estimated to be at risk, as a result of a hazard within the work system, is calculated by subtracting 5 from the TREC, then adding that number of zeros to 5.
2. Annual risk exposure (ARE) = TRE/projected life of work system.
3. Unit risk exposure (URE) = TRE/number of units.
4. Risk exposure ratio (RER) = TRE/total budget.

For example, consider the following scenario. A two-unit operation with a five-year projected life and $10 million total budget has a $1 million severity, giving you a correlated severity code of 6 (see severity code table). The same two-unit operation has a documented 0.01 rate of accidents, giving us a correlated exposure code of 5 (see exposure code table). Using the TREC matrix, you can find the correlated TREC of 11. Therefore, the following calculations are straight-forward:

1. Total risk exposure (TRE) = $5 \times 10^{(11-5)}$ or 5×10^6
2. Annual risk exposure (ARE) = 5×10^6 or $5,000,000/5 year or $1 million
3. Unit risk exposure (URE) = 5×10^6 or $5,000,000/2 units or $2.5 million
4. Risk exposure ratio (RER) = 5×10^6 or $5,000,000/$10,000,000 or 0.5

Focusing on the RER value, you could interpret this as saying that the two-unit work system currently has 50% probability of the risks incurring an accident. The strategy would then be to do a cost-benefit analysis of proposed controls using the hierarchy of controls that could be designed into the work system ultimately lowering the related severity and exposure values. Reducing severity and exposure then reduces the overall risk exposure ratio, or probability of the risks negatively impacting the work system to include the affected employees of the work system.

Now you can see exactly how the human and organizational perceptions of risks can be used to assess the risks within a system and how that assessed risk can then be used to evaluate the risk impact of the system. Notice how all of this is traceable back to the first unit where you were attempting to understand just how to use the as low as reasonably practical (ALARP) concept and ultimately to decide how to determine the point at which a work system is safe enough. This is precisely the goal of understanding system safety engineering. Once you understand what is safe enough for a work system, the necessary controls can then be designed into the system well before you expose humans and the environment to the work system. This is why you study how to engineer safe work systems, rather than to simply manage work systems with safety programs. This course has provided you the opportunity to work through some difficult concepts. Start using these skills in your own work environment, and let's save some lives!

References

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

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

Stephans. R. A. (2004). *System safety for the 21st century: The updated and revised edition of System Safety 2000.* Hoboken, NJ: Wiley.

Suggested Reading

In order to access the following resource. click the link below.

In this unit, you learned how to tie together the independent variables of human perceptions of risks, severity of risks. and total exposures to risks within a work system to effectively assess and evaluate the risks of the work system. This article demonstrates these three correlated variables.

Carrillo-Castrillo, J. A., Rubio-Romero J. C., Guadix, J., & Onieva, L. (2015). Risk assessment of maintenance operations: The analysis of performing task and accident mechanism. *International Journal of Injury Control and Safety Promotion, 22*(3), 267-277. Retrieved from https://libraryresources.columbiasouthern.edu/login?Auth=CAS&url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=108696273&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.

Evaluating the Risks within a Work System

Carefully reread the Unit VIII Lesson material related to qualitative risk assessment and quantitative risk evaluation. Select a work system that you know well. Do your best to determine the risk severity and the risk exposures of the work system. Calculate the risk evaluation report (RER) value, and then consider how to significantly decrease the probabilistic risk within the work systems using the hierarchy of controls. Feel free to send your work to your professor to evaluate and discuss with you.