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Applied Ergonomics Risk Assessment

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Abstract

Ergonomic risk factors are leading contributors to occupational injuries and illnesses in the form of workplace musculoskeletal disorders (WMSDs) and injuries from human error. Identification, assessment, and treatment of ergonomic risk factors should follow the established risk management process in ANSI/ASSP/ISO 31000 and 31010. While there are numerous ergonomics assessment methods, most are specifically targeted to body segments or specific tasks and applications and require advanced training and knowledge to use proficiently. One method, the Ergonomics Risk Assessment Tool (ERAT), can be applied to most applications by individuals with limited training. In this technical analysis, the authors present a case study demonstrating the multiple risk factors and risk summation theory using the ERAT.

Introduction

Workplace ergonomics can be defined as the applied science of designing workplace demands and environments to accommodate human capabilities and limitations for well-being and optimum performance (Popov, Lyon, Hollcroft, 2022). Such design factors optimize productivity by minimizing operator musculoskeletal stress, fatigue, discomfort, and error potential.

It's no secret that WMSDs make up 33% of occupational injuries and illnesses resulting in approximately 40% of all workers' compensation costs (Liberty Mutual) estimated to cost US businesses \$20 billion a year (U.S. Department of Labor.) These facts lead to the obvious need for businesses to better identify, assess and manage such risks.

Methodology

Ergonomic risk factor assessments, like all risk assessments, should follow the methodology established in the ANSI/ASSP/ISO 31000 and 31010 risk management and assessment standards. The risk management process model shown in Fig. 1 is a continuous process.

As with any risk management process, an assessment of ergonomic risk factors should begin with establishing the risk criteria, and context used in the risk assessment. Once established, ergonomic risk factors are identified, analyzed, and evaluated to determine their risk levels and need for treatment and management.

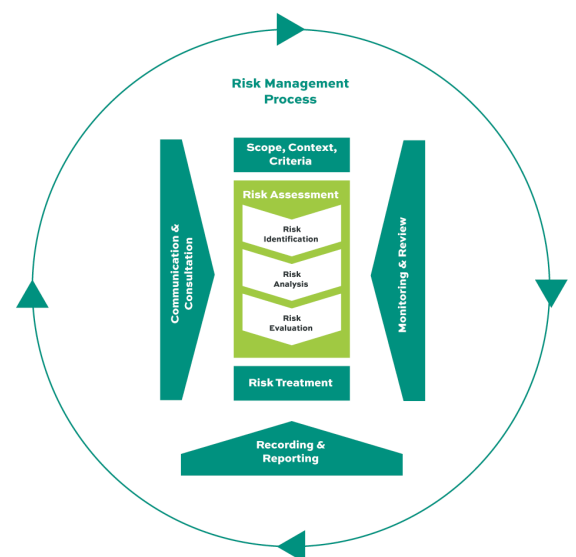


Figure 1 – Risk Management Process

Risk Factors

While considering the scope, context, and criteria, the existing ergonomic risk factors must be recognized or anticipated, identified, and assessed. Ergonomic risk factors are the aspects of a job or task that impose biomechanical stress on the worker. Such factors can have a synergistic effect on the body and contribute to WMSDs. OSHA examines a variety of exposures to ergonomic risk factors in the workplace in their OSHA 3125 publication titled: Ergonomics: The Study of Work (OSHA 2000). In this publication, OSHA included epidemiological studies, laboratory studies, and extensive reviews of the scientific evidence concluding that the following ergonomic risk factors are most likely to cause or contribute to a WMSD:

- Awkward postures
- Cold temperatures
- Contact stress
- Force
- Repetition
- Static postures
- Vibration
- We can probably add hot temperatures, lighting, contrast, and glare

According to OSHA (2000), force (forceful exertions), repetition, and awkward postures, especially when occurring at high levels or in combination, are most often associated with WMSDs. Ergonomic risk factors tend to be synergistic in effect. Individually, an ergonomic risk factor may not contribute a notable risk, however, when two or more risk factors are combined, the risk of biomechanical stress leading to a WMSD can be significantly increased. Tasks or activities that have multiple risk factors have a greater likelihood of causing a WMSD, depending on the duration, frequency, and/or magnitude of exposure to each. Workplace design, activities, and environmental conditions that may contribute to ergonomics-related risk factors include:

- Physical demands of work;
- Work area configurations, layout, and working/walking surfaces;
- Characteristics of object(s), tools, and materials that are handled or used; and
- Environmental conditions such as vibration, lighting, and temperature.

To illustrate how ergonomic risk factors can be assessed, the following case study is presented.

Case Study

Seaweed and algae are natural phenoniums found in most tropical regions because of climate. Unfortunately, as it washes up on beaches, it can create conditions that are unpleasant for tourists. As a result, it is often necessary to remove it manually from tourist-popular beaches as seen in Exhibit 1.



Exhibit 1 – Manual Removal of Seaweed

Since no single method can adequately assess the multiple risks associated with this type of task, a combination of methods is used including an ergonomics risk assessment methodology called Ergonomic Risk Assessment Tool or ERAT. Using the risk pathway model shown in Fig. 2, the elements of risk and their relationship can be considered in the risk assessment and treatment process.

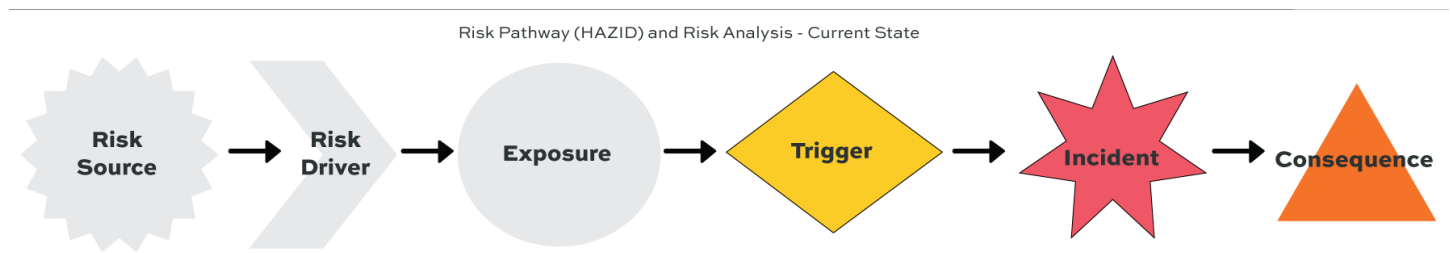


Figure 2 – Risk Pathway Model

Anticipate/Identify Risk

The first step in assessing risk is to identify the risk. This includes anticipating certain risks that could develop or are hidden. This step should describe the risk source, associated risk drivers that may influence the risk source, the exposure at risk, triggers or causes, and any existing controls. There are many identification methods available including the OSHA Ergonomics Assessment checklists, job hazard analysis (JHA), and the NIOSH Lifting Equation – Job Analysis Worksheet. However, there are some limitations to each of these methods. The OSHA Ergonomic Assessment Checklist is primarily designed for manufacturing/industrial operations. JHAs are not typically ergonomics specific or designed to identify ergonomic risk factors. And the NIOSH Lifting Equation is limited to calculating a recommended weight for specified two-handed, symmetrical lifting tasks. (RNLE) However, these hazard identification tools can be used in combination with other ergonomics risk assessment tools.

Risk Analysis and Evaluation

A number of methods can be used to analyze and evaluate ergonomic risk factors. A partial list is provided in Table 1 including their application, body segment, type, and degree of complexity.

Assessment Tool	Application	Body Segment	Type	Degree of Complexity
OSHA Screening Tool	General Industry Repetitive Tasks	Whole Body	Qualitative Checklist	Low
WISHA Checklists	General Industry Repetitive Tasks	Whole Body	Qualitative Checklist	Low
ACGIH TLV for Lifting	General Industry Lifting Tasks	Trunk	Qualitative Tables	Moderate
RULA	General Industry Repetitive Tasks	Upper Extremities Trunk	Semi-quantitative Worksheet	Moderate
REBA	General Industry Repetitive Tasks	Whole Body	Semi-quantitative Worksheet	Moderate
Snook Tables	General Industry Manual Handling	Trunk	Semi-quantitative Tables	Moderate
ACGIH TLV for Hand Activity	Office Settings Hand Work	Upper Extremities	Semi-quantitative Worksheet	Moderate
NIOSH Revised Lifting Equation	General Industry Manual Handling	Trunk	Quantitative Formula	High
UM Energy Expenditure Prediction Program	General Industry Manual Handling	Upper Extremities Trunk	Quantitative Software Program	High
UM 3D Static Strength Prediction Model	General Industry Manual Handling	Trunk Lower Extremities	Quantitative Software Program	High

Table 1 – Ergonomics Risk Assessment Techniques Partial List

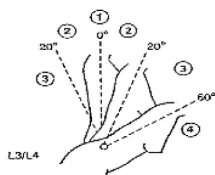
Results

In this case study, the Rapid Entire Body Assessment (REBA) method is selected due to its ability to identify and analyze upper limbs (arm, forearm, and wrist), lower extremities, trunk, and neck postures. For this method, body postures are observed, digitally recorded, and photographed for analysis using either posture diagrams and graphs (pictured in Fig. 3) or software applications. Different types of equipment can be used to measure angles and evaluate the risk in real-time. An example of a REBA semi-quantitative risk assessment is presented in Figs. 3, 4, and 5.

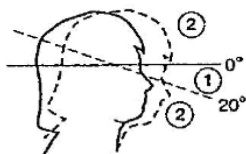
Position Calculations

Group A

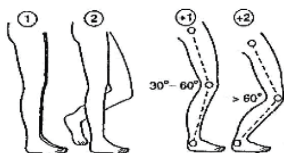
Posture/Range	Score	Total
Trunk		3
Upright	1	If back is twisted or tilted to side: +1
Flexion: 0-20° Extension: 0-20°	2	
Flexion: 20-60° Extension > 20°	3	
Flexion: > 60°	4	



Posture/Range	Score	Total
Neck		2
Flexion: 0-20°	1	If neck is twisted or tilted to side: +1
Flexion: >20° Extension: 20°	2	

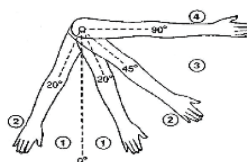


Posture/Range	Score	Total
Legs		2
Bilateral Wt Bearing; Walk; Sit	1	Knee(s) Flexion 30-60: +1
Unilateral Wt Bearing; Unstable	2	

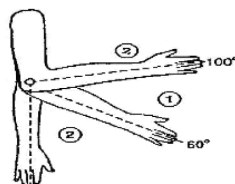


Group B

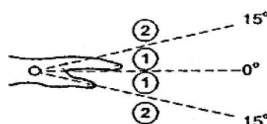
Posture/Range	Score	Total	
Upper Arms (Shoulders)		L 3	R 4
Flexion: 0-20° Extension: 0-20°	1	Arm Abducted/Totated: +1 Shoulder Raised: +1 Arm Supported: -1	
Flexion: 20-45° Extension: > 20°	2		
Flexion: 45-90°	3		
Flexion: > 90°	4		



Posture/Range	Score	Total	
Lower Arms (Elbows)		L 1	R 1
Flexion: 60-100°	1	No Adjustments	
Flexion: <60° Extension: >100°	2		



Posture/Range	Score	Total	
Wrists		L 1	R 1
Flexion: 0-15° Extension: 0-15°	1	Wrist Deviated/Twisted: +1	
Flexion: >15° Extension: >15°	2		



Score from Table A	5
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Posture/Range	Score	Total
Load / Force		2
<5 kg <11 lbs	0	Shock or Rapid Buildup: +1
5-10 kg 11-22 lbs	1	
>10 kg >22 lbs	2	

Score from Table B	L 3	R 4
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Posture/Range	Score	Total
Coupling		L 1 R 1
Good	0	Well fitting handle and a mid-range power grip
Fair	1	Hand hold is acceptable but not ideal or coupling is accessible via another part of the body
Poor	2	Hand hold is not acceptable although possible
Unacceptable	3	Awkward, unsafe grip, no handles. Coupling is unacceptable using any other parts of the body

Table A + Load/Force Score	7
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Table B + Coupling Score	L 4	R 5
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Figure 3 – REBA Position Calculations

Additional Factor

Score from Table A	5
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Posture/Range	Score	Total
Load / Force		2
<5 kg <11 lbs	0	Shock or Rapid Buildup: +1
5-10 kg 11-22 lbs	1	
>10 kg >22 lbs	2	

Score from Table B	L 3	R 4
---------------------------	------------	------------

Posture/Range	Score	Total
Coupling		L 1 R 1
Good	0	Well fitting handle and a mid-range power grip
Fair	1	Hand hold is acceptable but not ideal or coupling is accessible via another part of the body
Poor	2	Hand hold is not acceptable although possible
Unacceptable	3	Awkward, unsafe grip, no handles. Coupling is unacceptable using any other parts of the body

Table A + Load/Force Score	7
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Table B + Coupling Score	L 4	R 5
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Score from Table C	9
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Score from Table C	9	
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Activity	L 2	R 2
One or more body parts are static for longer than 1 minute	+1	
Repeat small range motions, more than 4 per minute	+1	
Rapid large changes in posture or unstable base	+1	

REBA Score	11
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Figure 4 – REBA Additional Factors

The last step of the ergonomics risk assessment process is risk evaluation. REBA is an important assessment tool since it provides an estimation of risk acceptability referred to as REBA Action Levels. In this case study, the REBA score of 11 is considered a very high risk, shown in Fig. 5.

Action Level			
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REBA Score	11
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Action Level	4
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Action is necessary immediately; this activity carries a very high risk for injury.			
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Action Level	REBA Score	Risk Level	Action
0	1	Negligible	None Necessary
1	2-3	Low	May be Necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary Soon
4	11-15	Very High	Immediately Necessary

Figure 5 – REBA Action Level Summary

The assessment method selected should include an assessment of all existing risk factors such as forceful exertions, repetition, duration, static or awkward postures, excessive reach, contact stress, vibration, poor lighting, unstable/slippery surfaces, cold/hot temperatures, humidity, and other factors. Most methods do not include lifting/lowering in an unfavorable environment such as extreme temperature and/or relative humidity. In fact, the revised NIOSH lifting equation does not include factors to account for unpredicted conditions, such as unexpectedly heavy loads, slips, or falls. Moreover, if the environment is unfavorable (e.g., temperatures or humidity significantly outside the range of 19° to 26°C [66° to 79°F] or 35% to 50%, respectively), independent metabolic assessments would be needed to gauge the effects of these variables on heart rate and energy consumption. (NIOSH LE <https://www.cdc.gov/niosh/docs/94-110/default.html>)

As previously mentioned, OSHA's JHA is not ergonomics specific and OSHA's Ergonomic Assessment Checklist does not include unfavorable conditions, unusual positions, heat stress, glare, and noise. Considering the limitations of these methods, a more encompassing tool such as ERAT can be used to assess and reduce specific ergonomic risk factors. ERAT was developed from the ergonomics checklist that was part of a working draft document by the Management of Work-Related Musculoskeletal Disorders Accredited Standards Committee (withdrawn in 2003) and can be used to assess ergonomic risks to upper extremities in most work environments including industrial, construction and agricultural settings. (Lyon, Popov, Hanes 2013; NSC 2002).

As demonstrated in Fig. 6 the initial assessment using ERAT finds the risk level to be 23 and an Action Level (AL) of 3, which requires immediate intervention.

Ergonomic Risk Assessment Tool (ERAT) - Initial Assessment						
Job Task: Seaweed Cleanup				Dept: Beach Maintenance	Date: 7/9/2020	
Risk Factor	Duration of Task			N/A	Score	Comments
	< 1 hr	1-4 hrs	>4 hrs			
Repetition	Enter Only One Score					
Every few minutes	0	0	1	N/A		
Every few seconds	0	1	3		3	rapid shoveling
Lifting	Enter Only One Score					
5 to 15 lbs	0	0	1	N/A		
15 to 30 lbs	1	1	2		2	shovels of sand
30 to 50 lbs	2	2	3	N/A		
Over 50 lbs	3	3	3	N/A		
Push/Pull Force	Enter Only One Score					
Easy	0	0	1	N/A		
Moderate	0	1	2		2	pushing shovel
Heavy	1	2	3	N/A		
Carry > 10 feet	Enter Only One Score					
5 to 15 lbs	0	0	1	N/A		
15 to 30 lbs	0	1	2	N/A		
Over 30 lbs	1	2	3	N/A		

Postures	Score Each					
Head Tilt	0	1	2		2	
Shoulder Reaching	0	1	2		1	
Flying Elbow	0	1	2		2	
Bent wrist/ pinch grip	0	1	2		1	
Bend or twist waist	0	1	2		2	pushing shovel
Environmental	Score Each					
Noise	0	1	2		0	
Lighting/glare	0	1	2		0	
Work/walking surface	0	1	2		2	uneven/unstable sand
Impact compression	0	1	2		2	shovel handle
Vibration	0	1	2		0	
Excessive Pace	0	1	2		2	physically demanding
Temperature/Humidity	0	1	2		2	high temp, sun, humid
	Action Level Total				23	
Action Level 1	Total score of 10 or less may require further analysis					
Action Level 2	Total score of 11 to 22 requires intervention in near future					

Figure 6 – ERAT Initial Assessment

Next, the assessor may suggest temporary improvements using the hierarchy of ergonomic risk treatments. For instance, mechanization using an open cab “seaweed tractor” may reduce some risk factors for WMSD and slips/falls. However, temperature extremes and high humidity risks are still present. The Hierarchy of Ergonomic Risk Treatment is shown in Fig. 7.

Hierarchy of Ergonomic Risk Treatment			
Method	Phase/Application	Examples	Effectiveness
Avoidance	Conceptual Stage Design/Redesign	Prevent entry of hazard into workplace by design through selection of technology and work methods.	High
Elimination	Existing Processes Redesign	Eliminate hazard by changes in design, equipment and methods	High
Substitution	Existing Processes	Substitute materials, sizes, weights and other aspects to a lower hazard severity or likelihood	Moderately High
Engineering Controls	Existing Workstations Redesign	Reduce hazard by changes to workplace, tools, equipment, fixtures, adjustability, layout, lighting, work environment	Moderate
Administrative Controls	Practices and Procedures	Reduce exposure to hazard by changes in work practices, training, job enlargement, job rotation, rest breaks, work pace	Moderately Low
Personal Protective Equipment	Workers	Reduce impact of hazard to employee by use of protective equipment and materials such as vibration attenuation gloves	Low

Figure 7 – Hierarchy of Ergonomic Risk Treatments

Using mechanization to remove seaweed will drastically reduce manual repetitive shoveling of sand and seaweed. However, it does introduce noise and vibration to the operator, as well as wrist and shoulder postures operating the steering wheel. The risk level is reduced to 11 which is an Action level (AL) of 2 as shown in Fig. 8.

Ergonomic Risk Assessment Tool (ERAT) - Follow-up Assessment						
Job Task: Seaweed Cleanup				Dept: Beach Maintenance	Date: 8/9/2020	
Risk Factor	Duration of Task			N/A	Score	Comments
	< 1 hr	1-4 hrs	>4 hrs			
Repetition	Enter Only One Score					
Every few minutes	0	0	1			
Every few seconds	0	1	3		0	eliminated

Lifting	Enter Only One Score					
5 to 15 lbs	0	0	1		0	eliminated
15 to 30 lbs	1	1	2			
30 to 50 lbs	2	2	3			
Over 50 lbs	3	3	3			
Push/Pull Force	Enter Only One Score					
Easy	0	0	1			
Moderate	0	1	2		0	eliminated
Heavy	1	2	3			
Carry > 10 feet	Enter Only One Score					
5 to 15 lbs	0	0	1	N/A		
15 to 30 lbs	0	1	2	N/A		
Over 30 lbs	1	2	3	N/A		
Postures	Score Each					
Head Tilt	0	1	2		1	slight tilt
Shoulder Reaching	0	1	2		1	tractor steering wheel
Flying Elbow	0	1	2		0	eliminated
Bent wrist/ pinch grip	0	1	2		1	tractor steering wheel
Bend or twist waist	0	1	2		0	eliminated
Environmental	Score Each					
Noise	0	1	2		2	tractor noise
Lighting/glare	0	1	2		0	
Work/walking surface	0	1	2		2	no change
Impact compression	0	1	2		0	eliminated
Vibration	0	1	2		2	tractor vibration
Excessive Pace	0	1	2		0	eliminated
Temperature/Humidity	0	1	2		2	No change

	Action Level Total	11	
Action Level 1	Total score of 10 or less may require further analysis		
Action Level 2	Total score of 11 to 22 requires intervention in near future		
Action Level 3	Total score of 23 to 36 requires immediate intervention		

Figure 8 – Action Level After Implementation of Mechanization

Further interventions that include higher level treatments should be investigated to reduce the risk level to an Action Level of 1.

Discussion

Overall, the ERAT is relatively easy to use and includes the assessment of repetition, lifting, push/pull force, carrying, postures, and environmental ergonomic risk factors. This technical analysis demonstrates the importance of including environmental conditions in the ergonomic risk assessment. In addition, an important concept in ergonomic risk assessment is understanding the additive or synergistic effects of multiple risk sources. Ergonomic risk assessment should consider whole system risk and risk summation. In fact, this technical analysis is a good example of how three well-recognized risks can result in greater additive risk. The authors would encourage readers to review BCSPs CSP Blueprint, where the risk summation technique is listed under Domain 2. The risk summation technique is presented in Figs. 9 and 10.

Current State										
Risk Source	Risk Driver	Exposure	Trigger	Existing Controls	Potential Incident	Potential Consequences (ERM)	Sev	Lik	RL	Risk Acceptable (Y/N)
Seaweed: weight, quantity	Stability of the load, length of operation	Beach cleaning operators	Twisting while lifting	Training	Ergonomics (Strain)-MSD to back, shoulder, neck, etc.	Disorders Operational ineffectiveness Financial losses Reputation damage	3	3	9	No
Heat stress	Excessive exposure to temperature and humidity	Beach cleaning operators	Extreme temperatures and humidity (ex. 110°F and 97%RH)	SOPs	Heat stroke, heat exhaustion, heat cramps, or heat rashes	Hospitalizations Operational ineffectiveness Financial losses Reputation damage	2	3	6	No
Gravity	Obstructed view. Tripping or slipping while carrying heavy loads	Beach cleaning operators	Slippery surfaces due to seaweed accumulation	Training	Heat stroke, heat exhaustion, heat cramps, or heat rashes	Minor injuries Operational ineffectiveness Financial losses Reputation damage	2	3	6	No
Risk Pathway (HAZID)							Risk Analysis		Risk Evaluation	

Risk Pathway (HAZID) and Risk Analysis - Current State

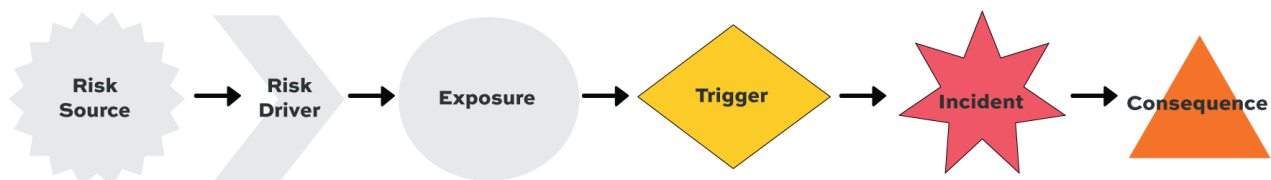


Figure 9 – Risk Pathway Model: Three Risk Sources

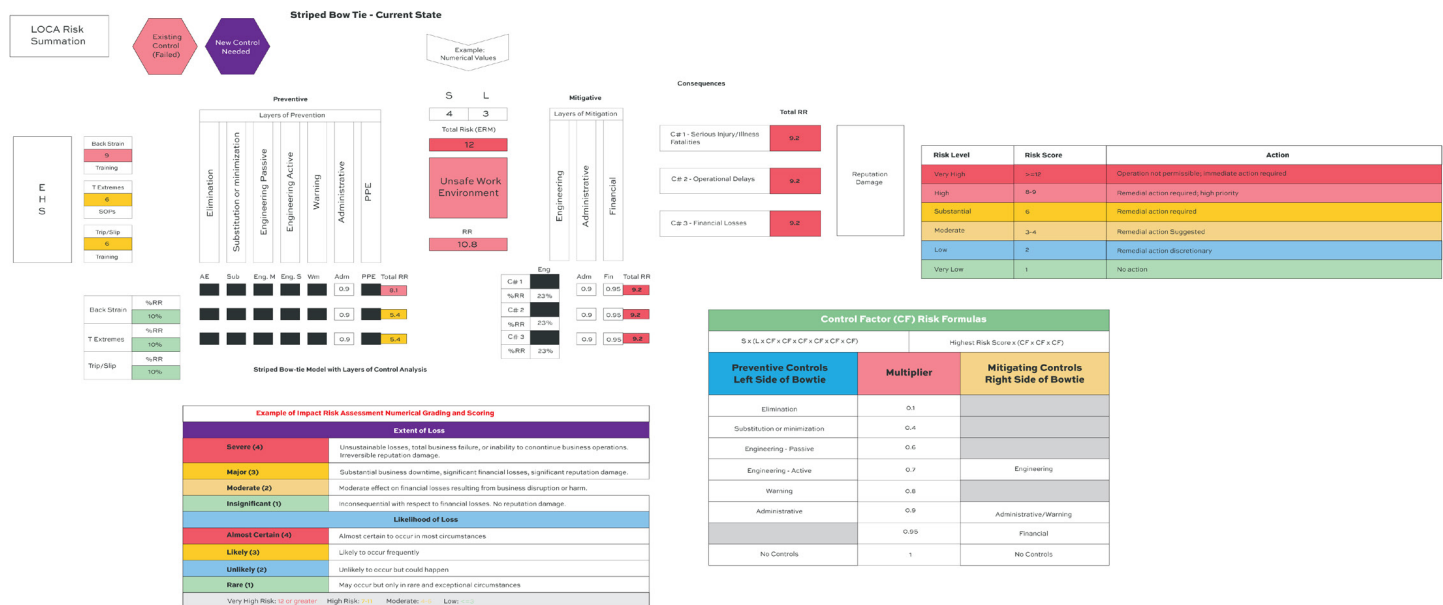


Figure 10 – Risk Summation Model Based on the Three Risk Sources

Excess nitrogen and phosphorus increase algae blooms. The root causes (reduction of phosphorus allowed to be discharged directly into water sources, eventually ending in the ocean) should be investigated. However, it will take years to address these issues.

Therefore, many companies are developing innovative solutions implementing higher levels of risk treatment. For instance, an innovative anchoring and turbidity curtain could be considered a solution that significantly reduces the amount of seaweed reaching the beach. An example is shown in Exhibit 2.



Exhibit 2 – Anchoring Curtain

Conclusion

OSH professionals are often reluctant to perform ergonomic risk assessments. However, ergonomic risk factors contribute to one third of the incidents and nearly 40% of the costs. OSH professionals have an opportunity to help decision makers reduce these risks and associated costs by assessing and treating specific ergonomic risk factors using higher level treatments. OSH professionals should identify and assess all existing ergonomics risk factors to consider and reduce whole system risk.

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