Construction Management and Project Engineering

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SEOUL NATIONAL UNIVERSITY

Unit 1 : Introduction

Unit 1 : Outline

- Overview of Construction Industry
- Cost of Accidents: Why Safety is Important?
- Accident Causation Models: Why Accidents Happen?
- Safety Management System: What We Are Doing Now?
- Emerging Technologies: How We Can Do Better?

Overview of Construction Industry (US)

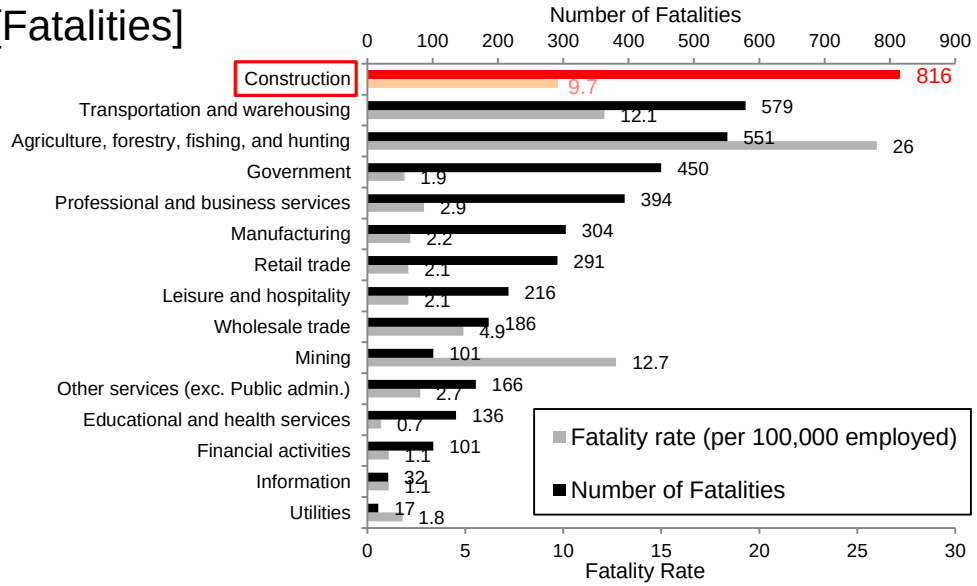
- Big business accounting for more than $600 billion in value annually
- Employing more than 4.5 million people (5% of US workforce)
- Death rate:
  - 4 per 100,000 (annually)
  - 17% of the workplace deaths
- One in seven workers is injured every year.

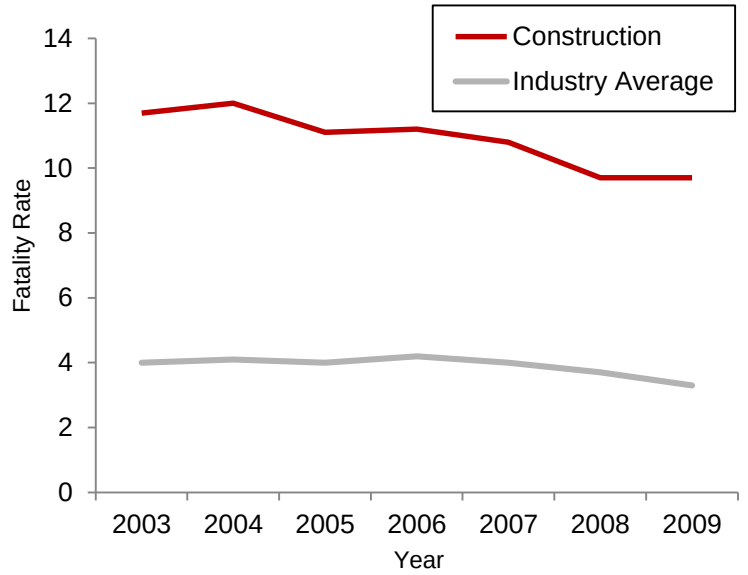
Specialization	SIC Code*
General contractor, single family	1521
General contractor, nonresidential	154
Highway & street construction	161
Bridge, tunnel, & elevated highways	1622
Plumbing, heating, & air conditioning	171
Painting, paperhanging, & decorating	172
Masonry, stonework, & tile setting	174
Plastering, drywall, & acoustical	1742
Carpeting & flooring	175
Concrete work	177
Structural steel erection	1792
Glass & glazing work	1793
Wrecking & demolition	1795

*Standard Industrial Classification, assigned by the U.S. Department of Commerce.

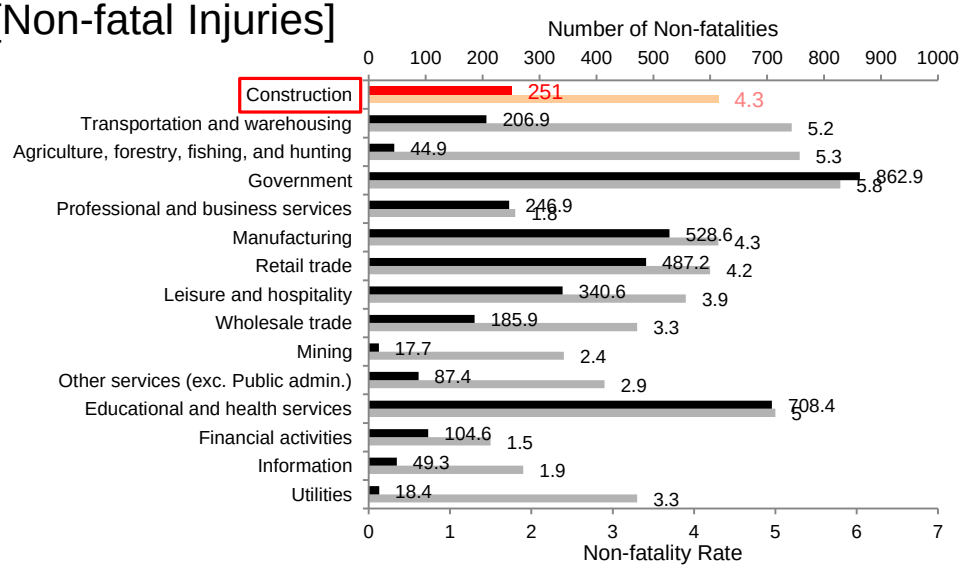
Construction Accident Statistics (US BLS 2009)

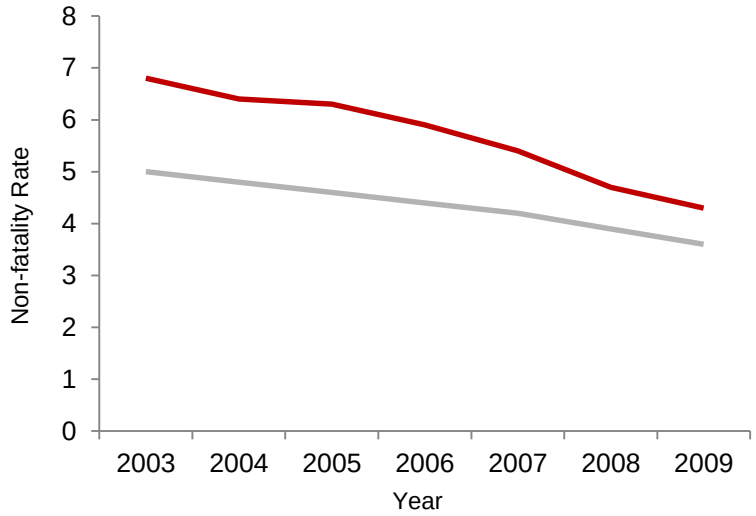
[Fatalities]





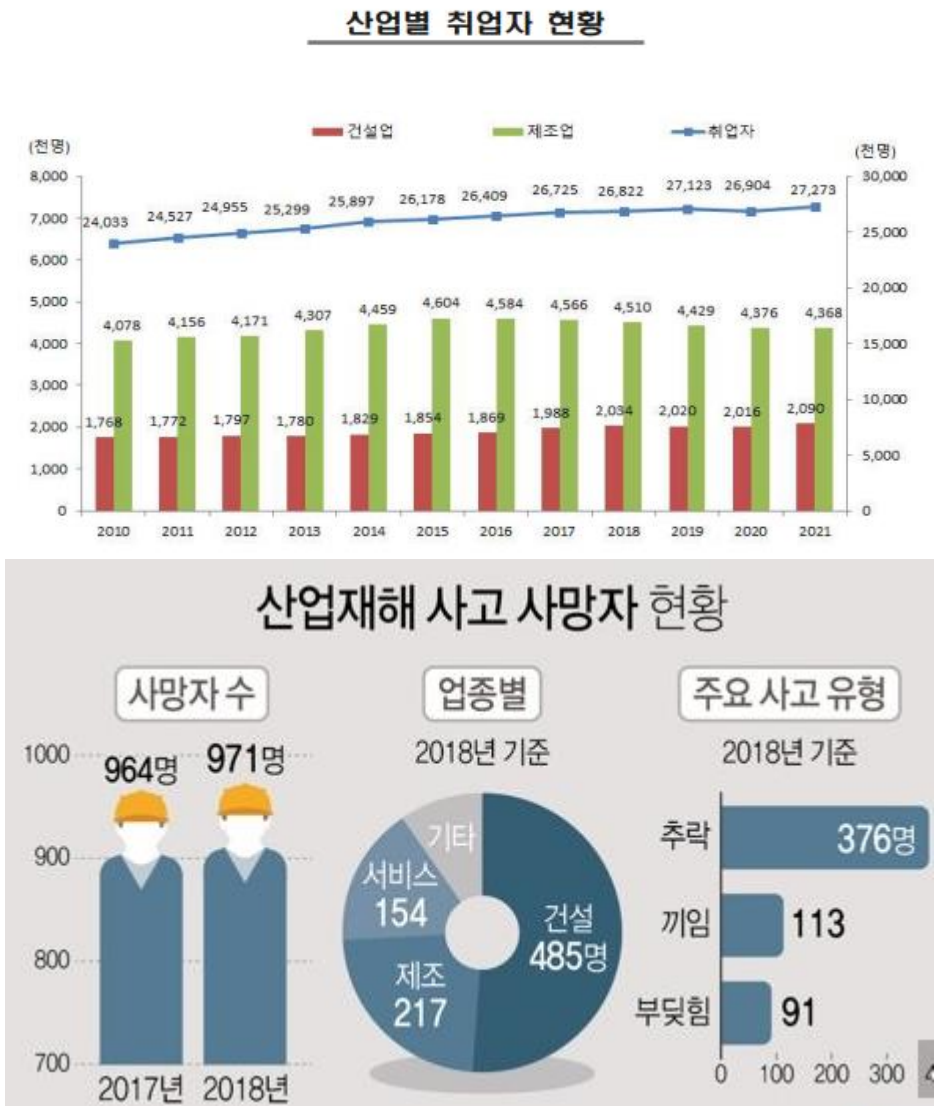
[Non-fatal Injuries]





Overview of Construction Industry (KR)

- The proportion of construction production accounts for 4.5% in GDP
- Employing more than 2 million people (7% of Korea workforce)
- Death rate (2020) :
  - 2 per 10,000 annually (average : 0.46 per 10,000)
  - 52% of the workplace deaths
- Why so dangerous?



Source : [주요건설통계, 2021, 대한건설협회]

Why So Dangerous

- Labor intensive
- Physically demanding
- Dynamic Jobsite
  - Quick turnover of staff
  - Unique projects, operations, and jobsites
  - Interaction with heavy equipment
- Involve working at great height

https://www.youtube.com/watch?v=pa0SFtmS--c

Liability in the Construction Industry

- Construction company can be held at least partially liable for the safety and health of workers, even when it is not the employer of record.
  - E.g., When an employee of a subcontractor is injured, the contractor and the subcontractor might be assigned shared liability.
  - A “target of opportunity” is a company with “deep pockets.”
- Contractors are expected to:
  - Be partially liable for the actions of their subcon
  - Exercise control over all aspects of a project

Cost of Accidents

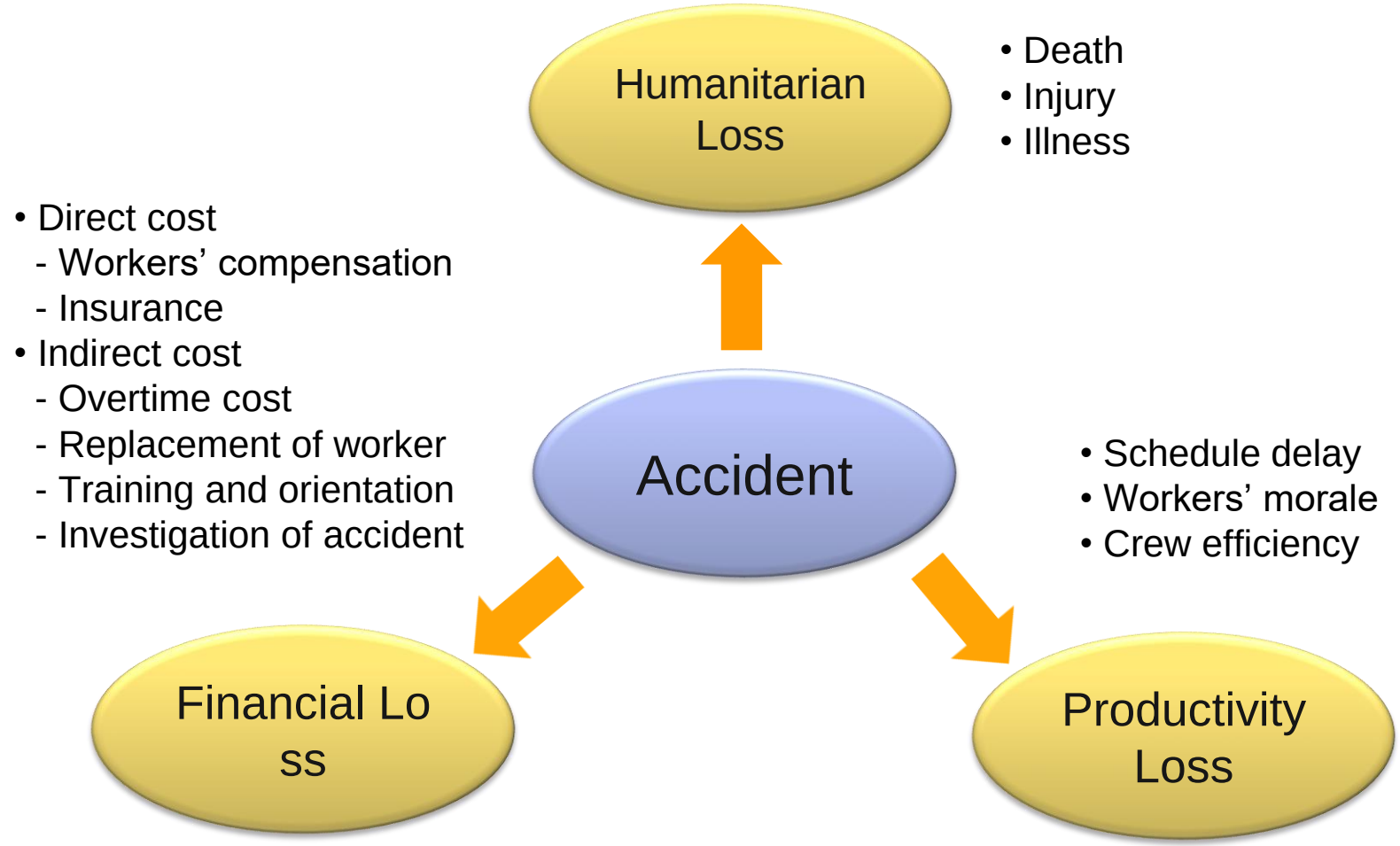
- While you make a 10-minute speech, two persons will be killed and about 170 will suffer a disabling injury. Costs will amount to $2.8 million.

- Costs include: Lost workdays, medical costs, property damage, indirect costs, insurance premiums and administrations

Motor vehicle accidents	$72.2
Workplace accidents	$48.5
Home accidents	$18.2
Public accidents	$12.5

Direct and Indirect Cost

- Impact of Accidents on Construction Projects



Cost of Accidents (US)

- Construction ranks third in workplace deaths (fatalities per 100,000 workers), but first in workplace injuries.

- Fatal Four for Construction
  - Falls (36%)

    https://www.youtube.com/watch?v=bCM0s2uqTz0
  - Struck by Objects (10%)

    https://www.youtube.com/watch?v=F_Li9_LUd2k
  - Electrocution (9%)

    https://www.youtube.com/watch?v=gFk1wh96abg
  - Caught in/between equipment (2%)

Cost of Accidents (KR)

- Construction ranks first in workplace deaths and in workplace injuries. (fatalities per 10,000 workers).

- Fatal Four for Construction

2020년 산업재해 사망자 882명 유형별 분석 (출처 :고용노동부)

1위	추락	37.2%(328명)
2위	기타	16.9%(149명)
3위	끼임	11.1%(98명)
4위	부딪힘	8.2%(72명)
5위	물체에 맞음	8%(71명)
6위	깔림뒤집힘	7.3%(64명)
7위	사업장외 교통사고	6.1%(54명)
8위	화재	5.2%(46명)

Source : [고용노동부, 2021]

Cost of Accidents

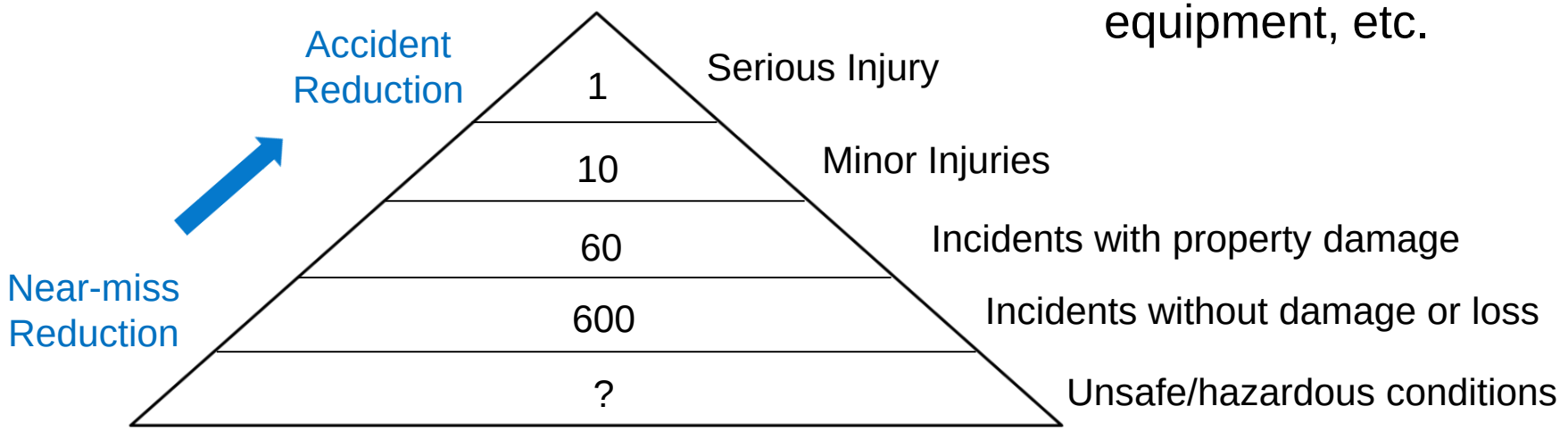
- Overexertion is the top cause of work injuries.
  - Back, Legs/fingers, Arms, Trunk
  - Estimated cost of overexertion: $9.8 billion (Fall: $4.4 billion)

Cost of Accidents: 6 surprising facts

1. One in ten construction workers are injured every year
2. Over the course of a 45-year career, a construction worker has a 1 in 200 chance of dying.
3. The most-violated OSHA standard is fall protection.
4. The job with the highest injury rates in the construction industry is ironwork
5. In 2012, Maine had <5 construction-related deaths. Texas had 105.
6. The construction industry is #2 in the United States for fatal injuries in workers younger than 18.

Safety Performance Measurement

- Lagging Indicators
  - "After the Fact": Measuring outcomes and occurrences (e.g., people are already injured.)
  - Examples: Total number of injuries and illnesses, lost time injuries, etc.
- Leading Indicators
  - "Prevention": Measurements associated with proactive activities to identify, assess, and mitigate hazard
  - Examples: Unsafe behaviors, unsafe acts and conditions, faulty equipment, etc.



[Near-miss incident theory (Phimister et al. 2003; Bird and Germain 1996)]

Safety Performance Measurement

➢ Incident Rates

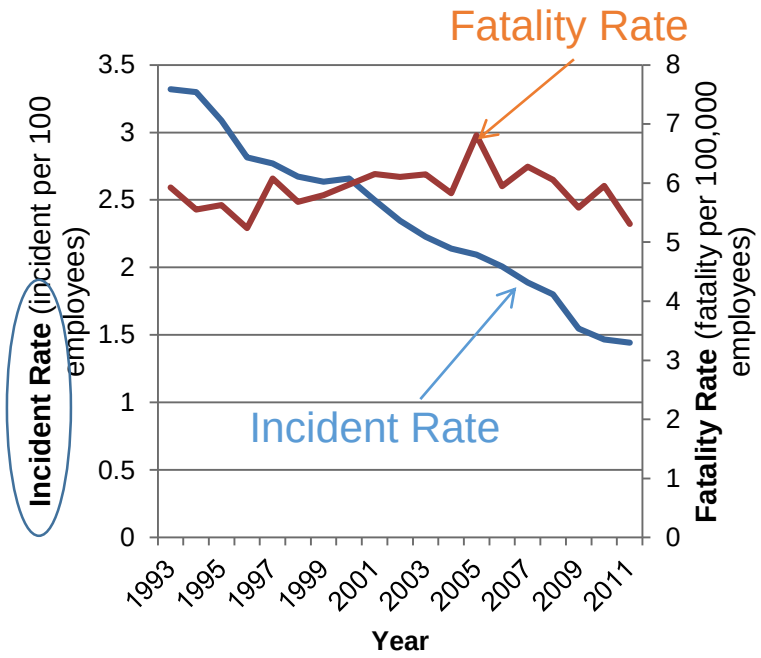
- The number of recordable injuries and illnesses occurring among a given number of full-time workers (usually 100 full-time workers) over a given period of time (usually one year).

✓Total Recordable Incident Rate (TRIR)

- Total number of recordable injuries and illnesses that occurred during the year

✓DART incident rate

- The incident rate for recordable cases involving days away from work, days of restricted work activity or job transfer (DART).



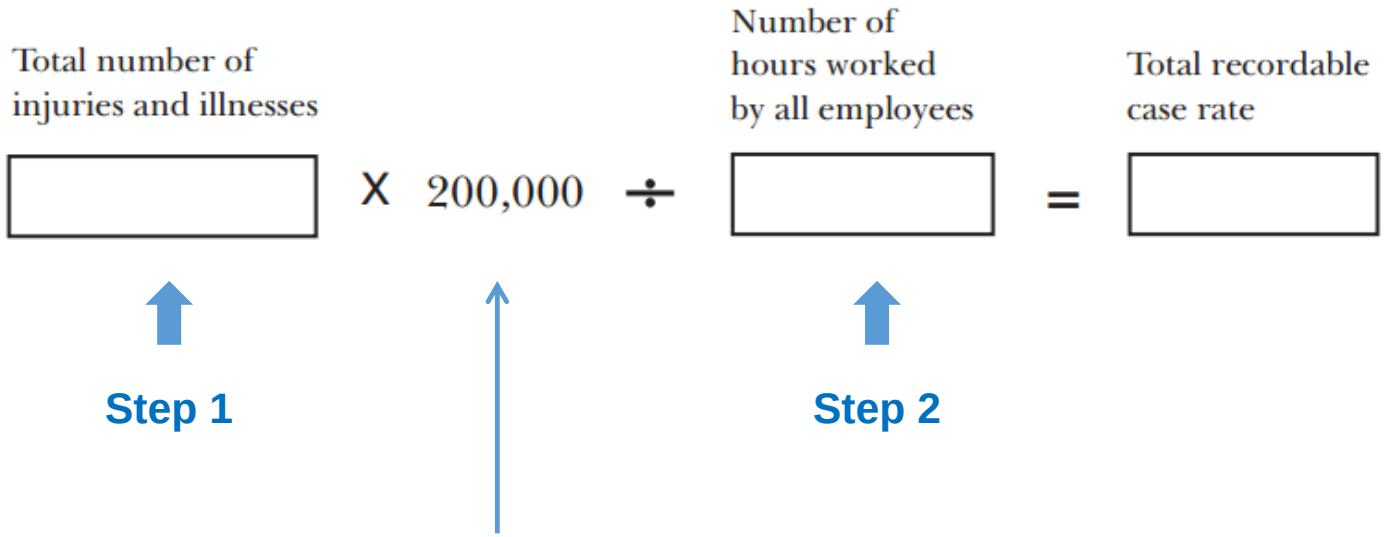
Safety Performance Measurement

- How to compute incident rates
  - Step 1: Count the number of incidents
  - Step 2: Calculate the number of hours all employees actually worked during the year

	_____	***Find*** the number of full-time employees in your establishment for the year.
X	_____	***Multiply*** by the number of work hours for a full-time employee in a year.
	_____	This is the number of full-time hours worked.
+	_____	***Add*** the number of any overtime hours as well as the hours worked by other employees (part-time, temporary, seasonal)
	_____	***Round*** the answer to the next highest whole number. Write the rounded number in the blank marked *Total hours worked by all employees last year.*

Safety Performance Measurement

- How to compute incident rates
  - Step 3: Compute the incident rate



100 employees working 2,000 hours per year
(normalized per 100 workers per year)

Why 2,000 hours per year?

Safety Performance Measurement

- Example: ABC Company
  - 7 injuries and illnesses logged
  - 3 cases that result in workers taking time off from their jobs or being transferred to another job or doing lighter (restricted) duties
  - General contractor with 200 employees
  - 2,000 average work hours for an employee (no overtime)

Safety Performance Measurement

- Example: ABC Company
  - 7 injuries and illnesses logged
  - 3 cases that result in workers taking time off from their jobs or being transferred to another job or doing lighter (restricted) duties
  - General contractor with 200 employees
  - 2,000 average work hours for an employee (no overtime)

Optional Worksheet

	200	***Find*** the number of full-time employees in your establishment for the year.
X	2,000	***Multiply*** by the number of work hours for a full-time employee in a year.
	400,000	This is the number of full-time hours worked.
+	0	***Add*** the number of any overtime hours as well as the hours worked by other employees (part-time, temporary, seasonal)
	400,000	***Round*** the answer to the next highest whole number. Write the rounded number in the blank marked *Total hours worked by all employees last year.*

TRIR

Total number of injuries and illnesses			Number of hours worked by all employees		Total recordable case rate
7	X 200,000	÷	400,000	=	3.5

DART

Number of entries in Column H + Column I			Number of hours worked by all employees		DART incidence rate
3	X 200,000	÷	400,000	=	1.5

Safety Performance Measurement

- Experience Modification Rate (EMR)
- Conceptually, the equation means:

$$EMR \approx \frac{\text{Actual Claims}}{\text{Expected Claims}}$$

- Measures that compares your “workers’ compensation” claims experience to other companies similar in size who operate in the same industry.
- To motivate a company to improve safety performance by decreasing the safety cost (i.e., workers’ compensation cost).
- Example: If you are at the industry average, your EMR is a 1.0. If your experience is 20% better, then of your EMR would be 0.80, while if 20% worse, then 1.20.

Safety Performance Measurement

- Experience Modification Rate (EMR)

- Reading
  - R. Gagne (2010). “Understanding the Experience Modification Rate (EMR): Review of Tools to Reduce Workers’ Compensation Costs.” Fit2WRK Clinical Educational Series, Volume 1.07.
  - J. Hinze, D. C. Bren, and N. Piepho (1995). “Experience Modification Rating as Measure of Safety Performance.” Journal of Construction Engineering and Management, 455-458.

Accident Causation Models

Why Accidents Occur?

- Domino Theory of Accident Causation
- Human Factors Theory of Accident Causation
- Accident/Incident Theory of Accident Causation
- Epidemiological Theory of Accident Causation
- Systems Theory of Accident Causation
- Behavioral Theory of Accident Causation

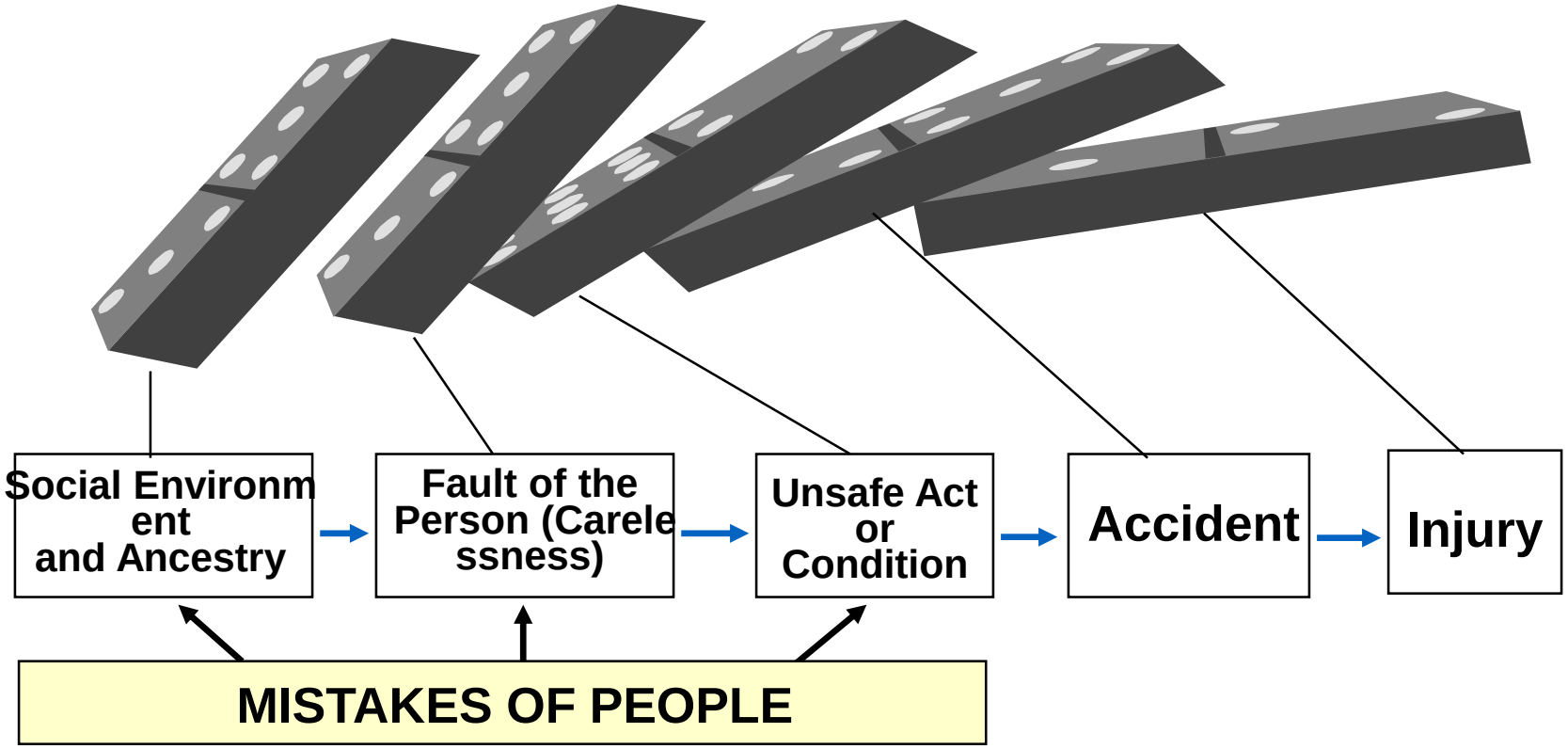
Accident Causation

- Definition of an Accident
  - “An unexpected, undesirable, and unplanned event or circumstance that may often result in an injury or property damage”

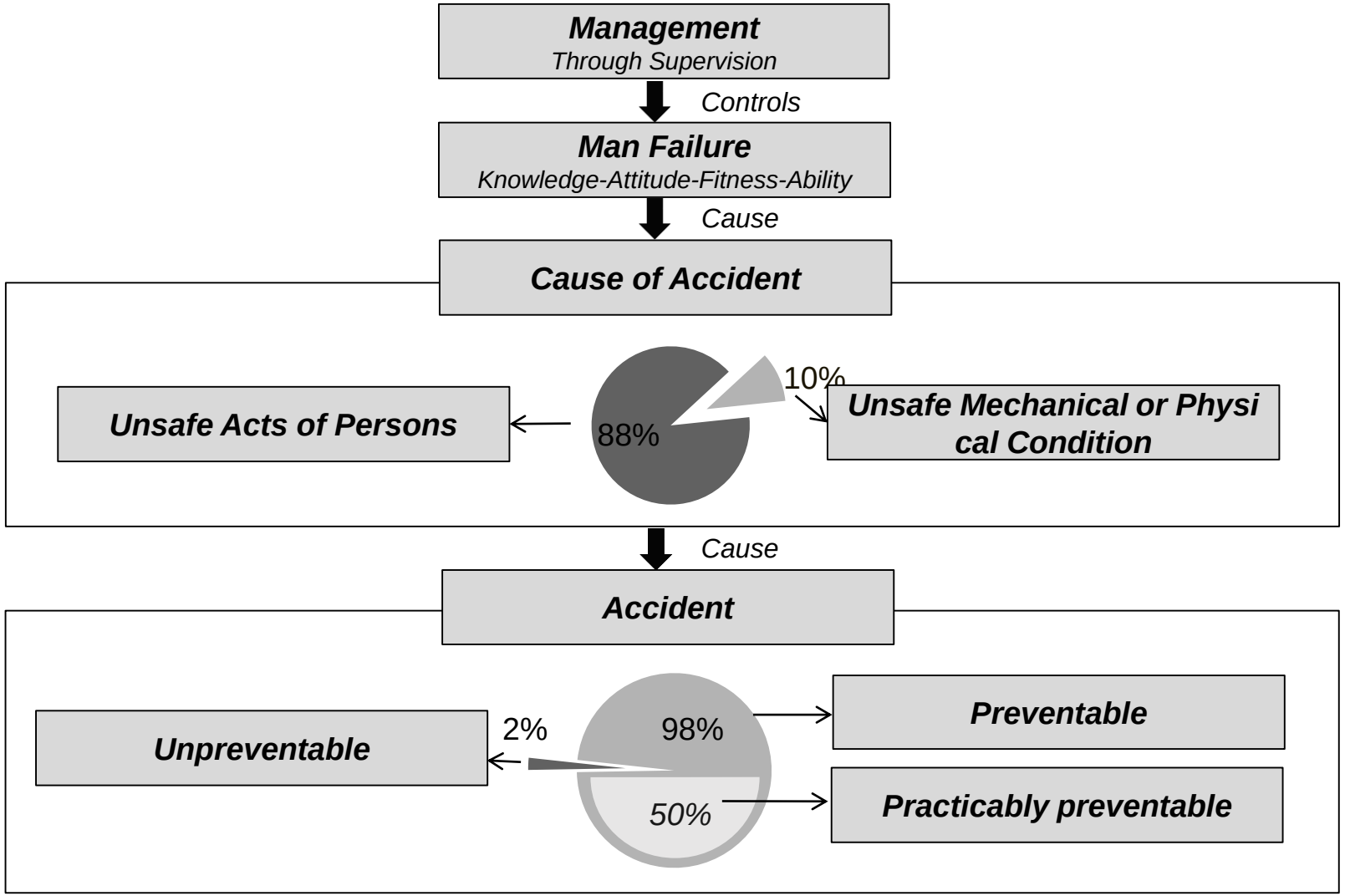
- Accident Causation for Prevention
  - To prevent accident, we need to know why accident happen and what causes them.
  - Accident Causation Theories are used as models to help understand, predict, and prevent accidents.

Accident Causation: Domino Theory

- Sequential Model: The First Scientific Approach to Accident Prevention by H. W. Heinrich in 1932



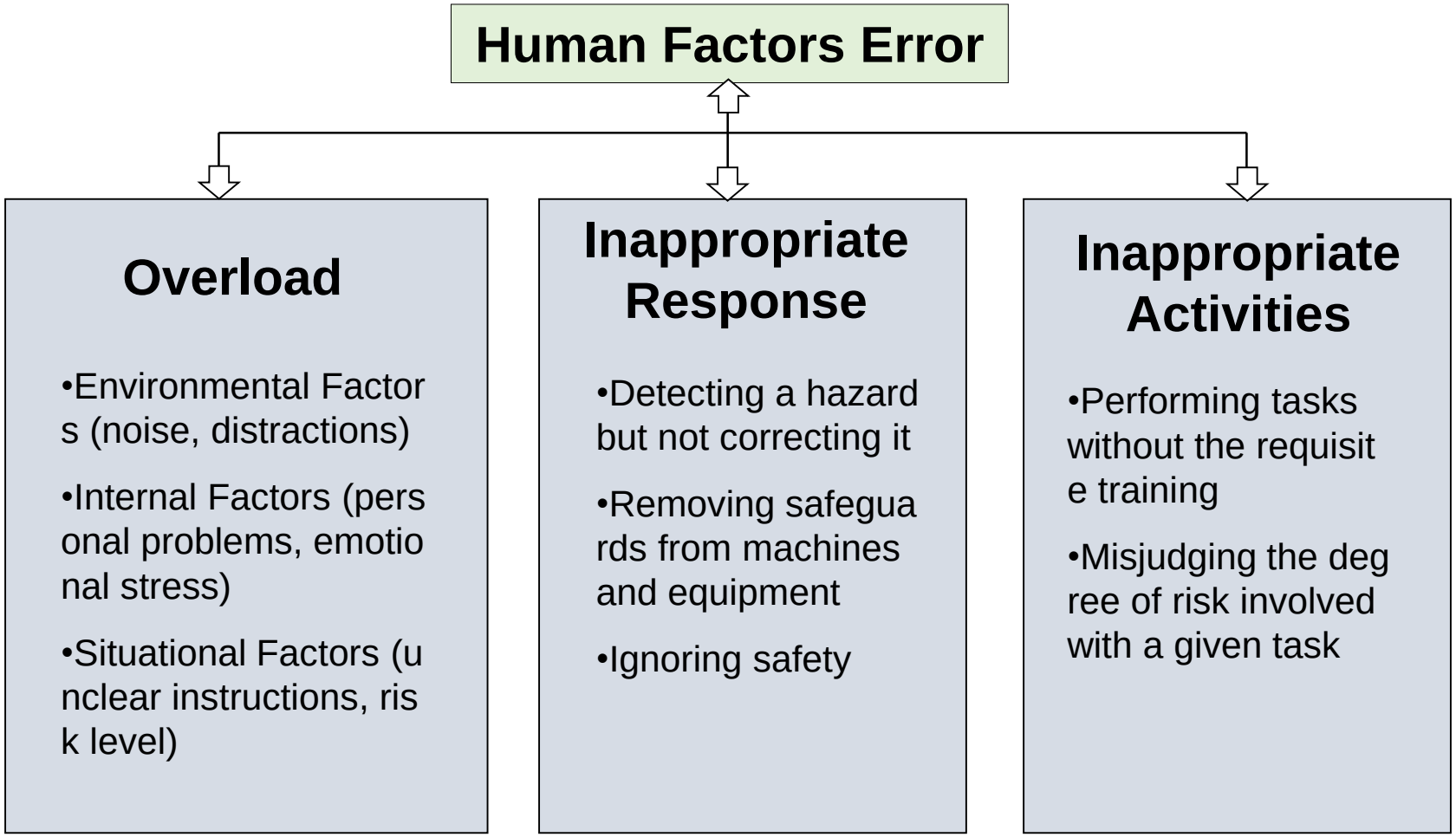
Accident Causation: Domino Theory



[Heinrich, H. W., Petersen, D., and Roos, N. (1980). Industrial accident prevention, McGraw-Hill, Inc., New York.]

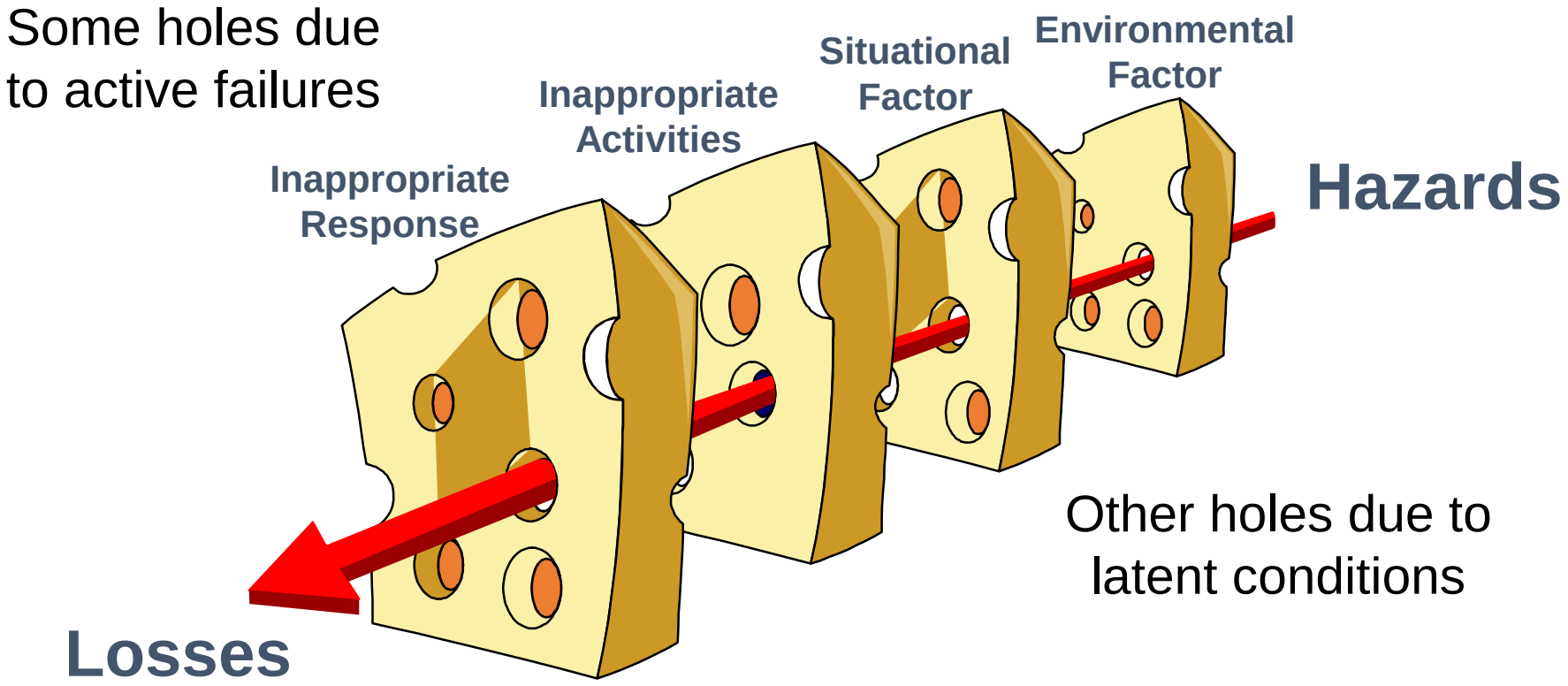
Accident Causation : Human Factors Theory

- Chain of Events caused by Human Error

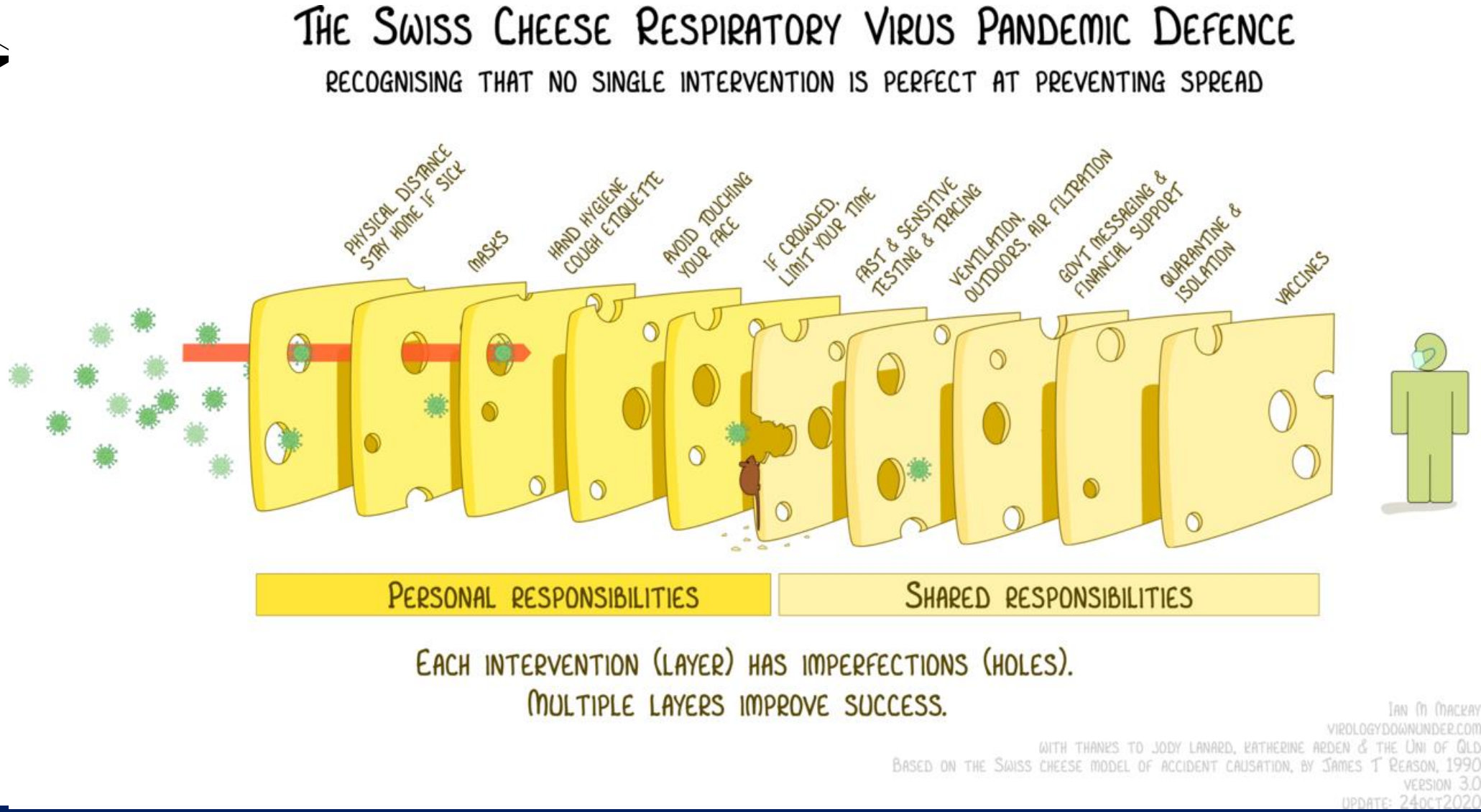


Event-Chain Causality Models

- Swiss Cheese Model: Combination of at-risk conditions

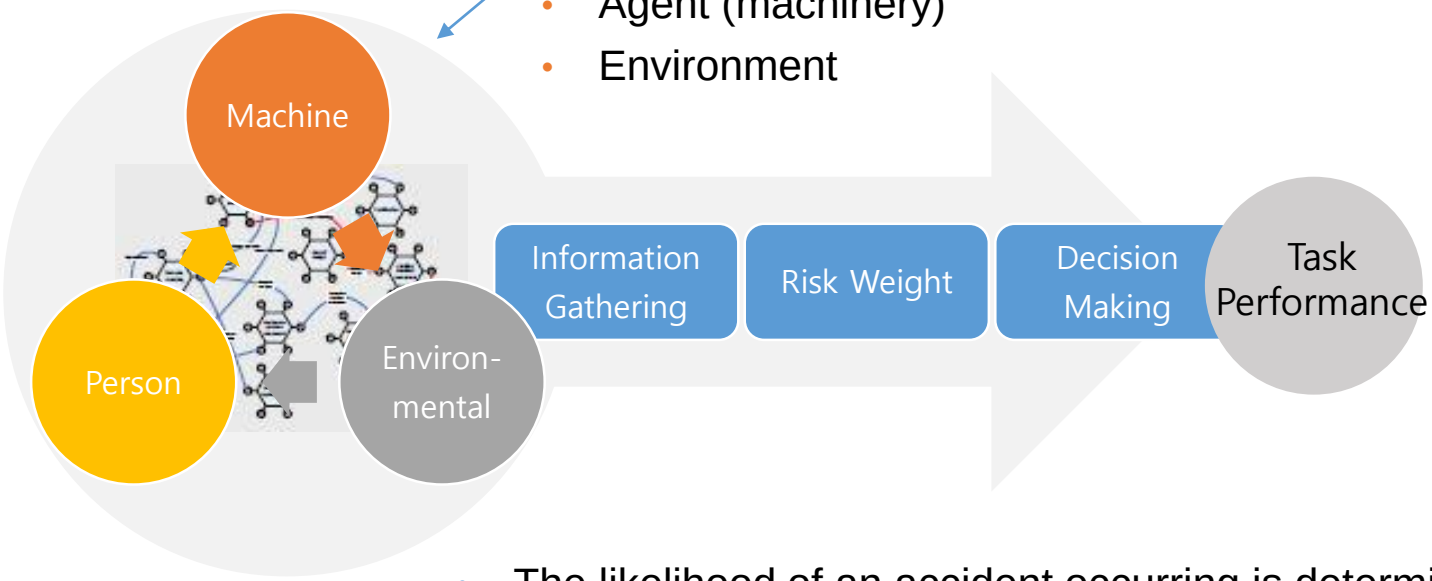


Swiss Cheese: Covid Spread



Accident Causation: Systems Theory

- Combination and Interaction of system components
  - System is a group of interacting and interrelated c omponents that form a unified whole.
    - Host (people)
    - Agent (machinery)
    - Environment



System

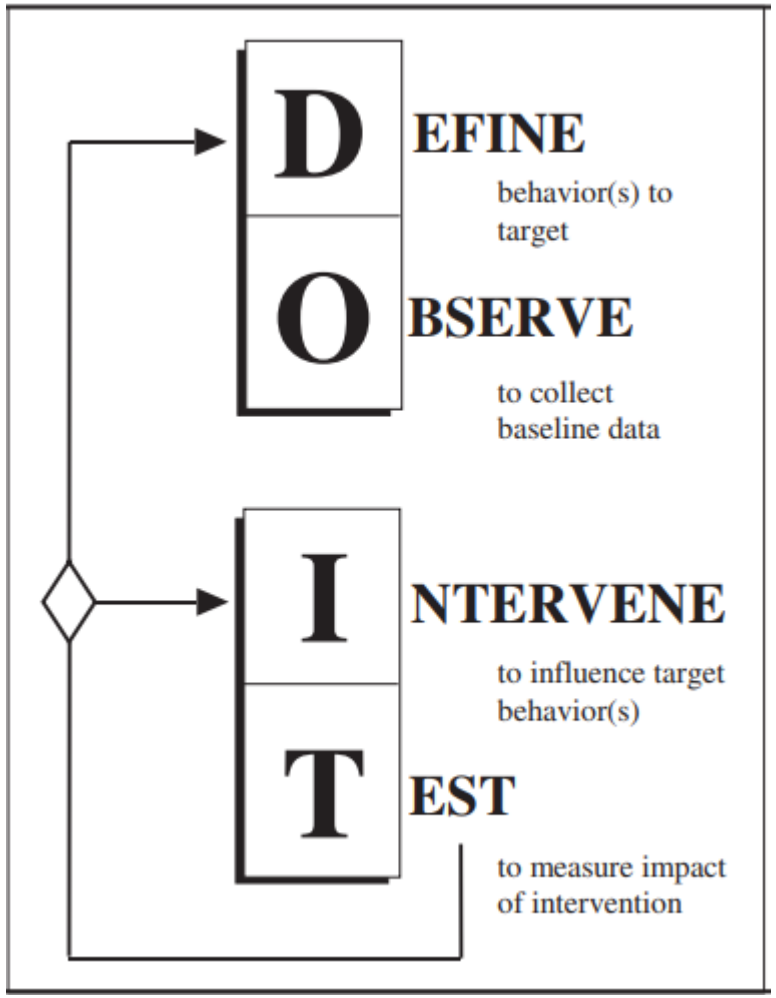
- The likelihood of an accident occurring is determined by how these components interact.
- Changes in the patterns of interaction can increase or decrease the probability of an acci dent occurring.

Accident Causation: Systems Theory

- Safety is an emergent property that arises when components of system in teract
  - A set of constrains related to behavior of components in system enforces that propert y
  - Accidents when interactions violate those constraints (a lack of appropriate constraint s on the interactions)
  - Software as a controller embodies or enforces those constraints

Behavioral Theory of Accident Causation

1. Use intervention that is focused on employee behavior.
2. Identify external factors that aid in understanding and improving employee behavior.
3. Direct behavior with activator or events antecedent to the desired behavior, and motivate employees to behave as desired with incentives and rewards that follow desired behavior.
4. Focus on the positive consequences that result from the desired behavior as a way to motivate employees.
5. Apply scientific method to improve attempts at behavioral interventions.
6. Use theory to integrate information rather than to limit possibilities.
7. Plan interventions with the feelings and attitudes of the individual employee in mind.



Observer: Date:

Target Behavior	Safe	At-Risk
load appropriate		
hold close		
use legs		
move feet - don't twist		
smooth motion - no jerks		
Comments (use back if necessary):		

% Safe Observations:

$$\frac{\text{Total Safe Observations}}{\text{Total Safe Observations + At-Risk Observations}} \times 100 = \_\_\_\_\_ \%$$

Limitations of Each Theory

Theory	Limitations
Domino	Each of the factors is dependent on the preceding factor Simplify the control of human behaviors
Human Factors	Not a single domino. Multiple dominos Ignoring the role of management behaviors/roles
Accident/incident (Petersen's)	Includes system failure (policy, training) Does not adequately account for human error. Cannot be isolated from contexts.

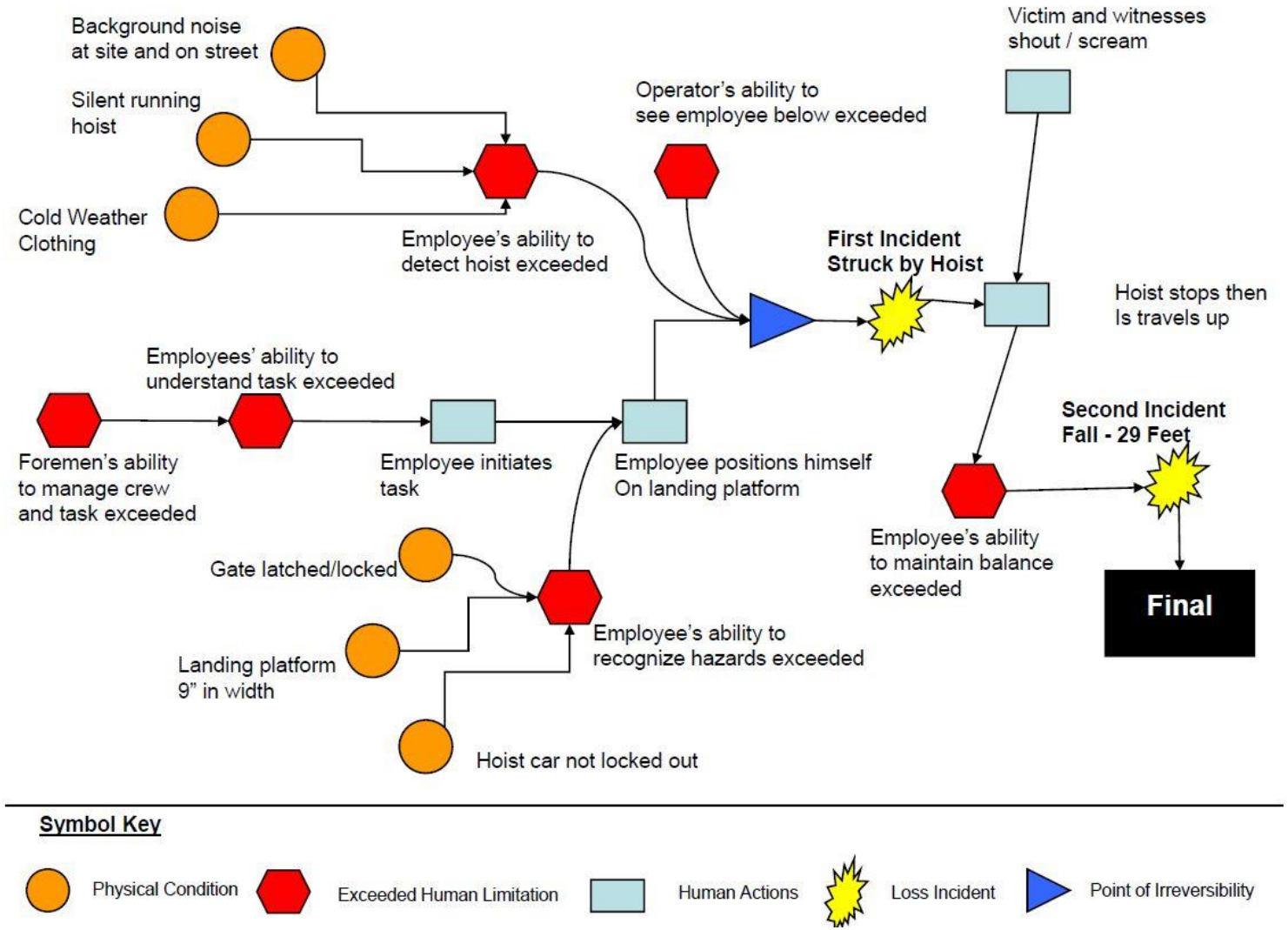
Accident Causation: Combination Theory

- For some accidents, a given model may be very accurate, for others less so.
- Often the cause of an accident cannot be adequately explained by just one mo del/theory.
- Actual cause may combine parts of several different models.

Causation Models and Management Trends

- Classical Management (1950s)
- Human Relations Management (1960s)
- Situational Management (1970s)
- Cultural Management (1980s)
- Downsizing, TQM, and Reengineering (1990s)
- Sustainability, Corporate Social Responsibility (2000s)

Universal Model Diagram: Example



Five Ys Technique: Examples

Proximal Causal Factor From Model	Why?	Why?	Why?	Why?	5th Why?
 Foremen's ability to manage crew and task exceeded	Foremen did not follow pre-task plan as agreed one week prior	Management did not walk foremen through plan day of incident	Manager assigned task oversight to less experienced staff member	Project team staffed with less experienced staff	Company experiencing high work volume and availability of experience staff scarce.
 Employee's ability to understand task exceeded	Foremen did not follow plan. Specifically brief crew prior to execution	Pre-task planning and briefings not in writing.	Management has not fully implemented pre-task planning as a basic requirement. Developed ad hoc.	Corporate has not fully developed or embedded a pre-task planning process as part of the systems	Corporate Safety procedure update long overdue. No dedicated staff assigned to develop, upgrade and maintain program.
 Employees' ability to recognize hazards exceeded	Employee did not attend New Hire Safety Orientation Program	Employee's foremen did not insist on employee attending orientation	Subcontractor did not adequately communicate policy to 3rd Tier subcontractor	Management team did not implement program to address all workers prior to work on site	Project teams struggle with implementing an effective orientation program
 Hoist cars not locked out	Pre-task plan references "locking out" hoist, not executed.	No formal Lock-out program submitted by subcontractor	Project team did not anticipate the need for a lockout procedure for subcontractor	Pre-con risk assessment not completed to this level of detail	Pre-con risk assessment relies too heavily on PM knowledge of hazards

Five Ys Technique: Corrective Actions

5th WHY	Actions Forward
Company experiencing high work volume and availability of experience staff scarce.	Several efforts being rolled out to address this include: •Decrease time between hire date and initial safety training of all management staff to include those promoted to field positions where they did not perform at that capacity in the past •Training course being rolled out this month to clarify Best Practice •HR to evaluate recruitment resources to attract more candidates
Corporate Safety procedure update long overdue. No dedicated staff assigned to develop, upgrade and maintain program.	•Overall haul of Corporate Safety SOPs prioritized for 6 month rollout •Staffing plan to be developed to provide dedicated team to work on program.
Project teams struggle with implementing an effective orientation program	•Safety Department to standardize orientation process and roll out to all projects. Program to include effort to provide orientation package for project team implementation, focused training to direct hire labor, drill down to 3rd Tier subcontractors. •Legal to incorporate contract language to address requirements for new hire orientation of subcontractors.
Pre-con risk assessment (RR) relies too heavily on PM knowledge of hazards	•Corporate Safety to generate a list of high hazard tasks and develop control measures and pre-task planning agendas for the same •Key Operations staff to participate in a detailed assessment of the current pre-construction risk assessment process to enhance usability and effectiveness.

Five Ys Technique: Organizational Mitigation

Broad View	Commentary
Project Culture	An evaluation of the following influences on staff should be conducted: •Project Team Size - Are project teams too lean? Do systems need to be evaluated and upgraded to compensate? •Performance Incentives – What influence do they have on project team performance in safety (both Company and Owner Controlled Incentives)? •Safety Measures in Incentive Compensation – Are they working? Are we measuring the right things? Is the system fair? Percentage weighting enough?
Safety Systems	•Safety Program – Are current Safety systems able to support project team needs? Is a major upgrade needed? How does OHSMS certification play into this? How do new Safety policies get communicated/rolled out? •Pre-Construction Safety Input – What is the status of recent efforts by Pre-con to address safety in early stages of project lifecycle? •Safety Support Services – Do project teams understand the roles of safety staff on their site? What are the roles & responsibilities of project safety staff?

Assignments

- Please construct a case study on a construction accident and provide a presentation on March 10th.

  1. Fatal Four accidents in construction are preferred.

  2. Select one case and do detailed research using news media, NIOSH FACE reports, KOSHA reports, and others.

  3. Deliver the full details of an accident: How and why it happened.

  4. Describe (guess) the potential causes of the accident by (1) applying the universal model diagram, (2) 5Ys technique, or (3) any causation model.

  5. (Optional) Do a research on its settlement/compensation and deliver how it was settled. (you can search its related law suit/compensation claim dispute from "Google Scholar" - Case Law - Select related courts)

- Each team should consist of 2 ~ 3 team members, and is given 15 min.

What are we doing?

- Compliance with OSHA (Occupational Safety and Health Administration) rules
- Management Leadership
- Worker Participation
- Hazard Identification/Assessment
- Hazard Prevention/Control
- Education/Training
- Communications and Coordination for Employers on Multiemployer worksites

How can we do better?

- Wearable Sensors: Tracking workers' locations and biosignals
  - Locations: RFID, Bluetooth, UWB, Ultrasound.
  - Physical motions: IMUs
  - Physiological responses (e.g., overexertion, stress, attention)
  - EDA, ECG, EEG, PPG, Eye tracking
- VR/AR: training or providing information in a better way
- Others..

How can we do better?

- Spot-r:

https://www.youtube.com/watch?v=UqY4Bd88DL4

https://www.youtube.com/watch?v=xXvLaKpoa5E

Any Question?