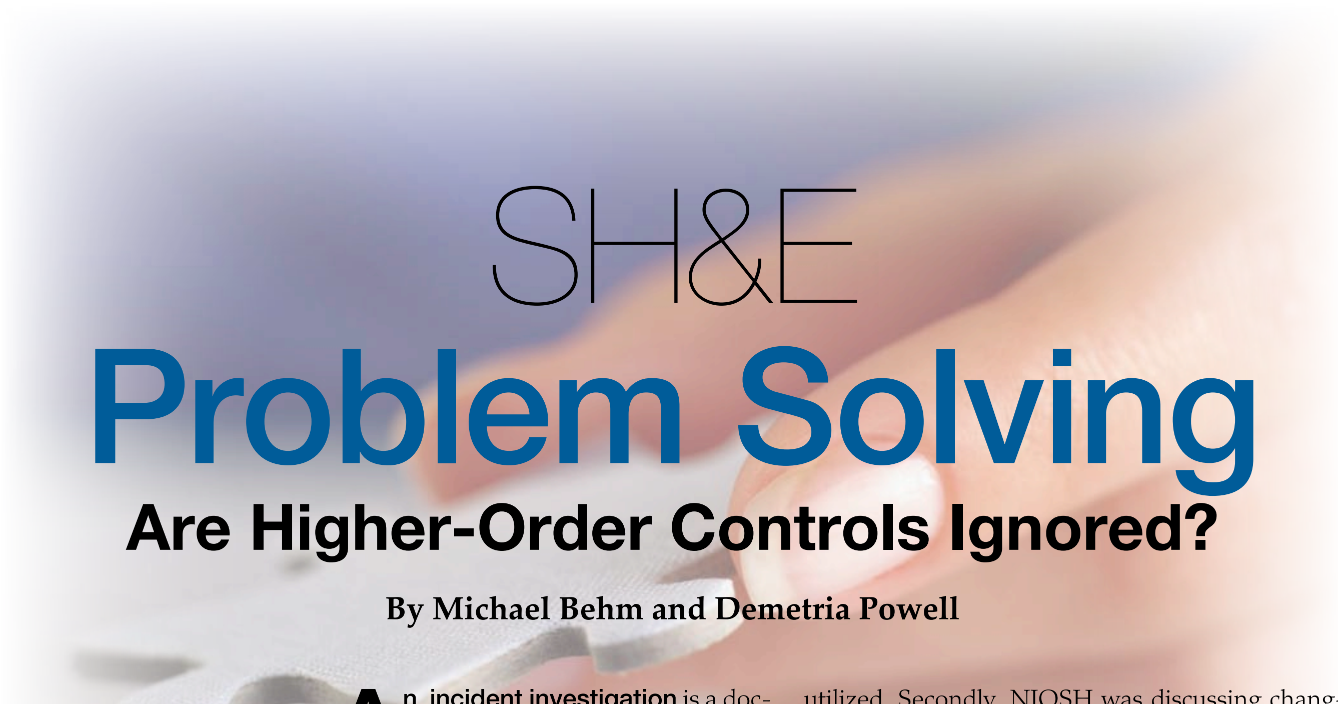

SH&E Problem Solving

Are Higher-Order Controls Ignored?

By Michael Behm and Demetria Powell

IN BRIEF

- **Incident investigations can be a valuable source for organizational learning. Deficiencies in risk mitigation can be identified leading to meaningful solutions.**
- **Incident investigations were evaluated to determine the types of failures identified and solutions recommended.**
- **While organizations have begun to solve problems with an eye toward higher-order controls, the focus remains squarely on a single source and on those closest to the operation. Solutions are focused on administrative controls.**
- **Safety professionals and their organizations should look upstream into the management and work systems during investigations as sources for organizational learning that will ultimately improve safety.**

An incident investigation is a documented and discoverable analysis of how an organization solves occupational safety and health (OSH) issues stemming from incidents and near misses. SH&E professionals should care about the method of problem solving that occurs within their organizations.

Investigating incidents has long been one method to identify unacceptable risk and suitable countermeasures. The shortcomings identified by investigators are crucial to how their organizations will solve and reduce unacceptable safety and health risk. What is learned and recommended from incident investigations ultimately determines their effectiveness. Various researchers highlight the need for additional organizational learning from incidents (Behm & Schneller, 2013; Fahlbruch & Schöbel, 2011; Hopkins, 2008; Kletz, 2006, 2002; Lindberg, Hansson & Rollenhagen, 2010; Stoop & Dekker, 2011).

The years 2005 through 2007 are significant in demarcating a possible shift in safety professionals' decision making and problem-solving knowledge and practice. First, ANSI Z10, a U.S. consensus standard for Occupational Health and Safety Management Systems, was approved on June 25, 2005. The standard states that to achieve feasible risk reduction the hierarchy of controls should be utilized. Secondly, NIOSH was discussing changes in thinking about OSH problem solving. The agency hosted the first Prevention Through Design (PTD) Workshop in Washington, DC, July 9-11, 2007. The workshop launched a national initiative to eliminate occupational hazards and control risks to workers at the source or as early as possible in the life cycle of items or workplaces.

Furthermore, Manuele (2011) notes there is a transition in the practice of safety that places greater emphasis on the hierarchy of controls, hazard identification and analysis, risk assessments, and the design of the workplace and work methods. He uses 2005 as a starting point to list global developments that focus on risk assessment and the hierarchy of controls.

Further evidence in a shift in thinking can be found searching the literature. For example, a ProQuest database search was utilized to search articles published in *Professional Safety* for the term *behavior based safety* in the manuscript title. Twenty manuscripts were found dating back to 1985; only three of them were post-2000, with the latest one in 2005. This signifies a shift is what is being written about and read by safety professionals.

Taken together, do these changes translate into practice? While not every company has implemented PTD or ANSI Z10, the hierarchy of controls is not a new concept. It has been around in industrial hygiene since Hamilton (1929) and in safety since at least Haddon (1973).

The hierarchy of controls "provides a systematic way to determine the most effective method to re-

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duce risk associated with a hazard" (ANSI/AIHA/ASSE, 2012, p. 15). The hierarchy of controls specified in the Z10 standard has six solution categories. In order of preferred problem solving efficacy, they are: elimination; substitution of less hazardous materials, processes, operations or equipment processes; engineering controls; warnings; administrative controls; and PPE.

Culvenor (2006) analyzed organizational decision making with respect to the hierarchy and grouped the first three as higher-order controls, and the last three as lower-order controls. Culvenor concludes that it is easier for organizations to solve problems using lower-order controls, whereas higher-order controls are sometimes difficult to develop and implement, even though they have the ability to fundamentally change the work.

Culvenor (2006) contends that higher-order control solutions are often brushed away as being far-fetched. Solving OSH problems with elimination, substitution and engineering controls is difficult and requires effort; however, the creative potential to truly impact OSH and business measure is worth the effort.

An issue with developing higher-order solutions stemming from incident investigations is that "investigators are usually so close to the job that their main objective is to correct the immediate technical faults that caused the incident and get the plant back on line; putting the world right is not their problem" (Kletz, 2006, p. 74). Kletz concludes that "investigators may be in a difficult position when they feel that an underlying cause of an accident is the organization's policy or culture" (pp. 74). This may explain why investigators still often recommend lower-order controls despite the recent emphasis on design and the hierarchy of controls.

A lack of proper utilization of the hierarchy of controls can lead to larger issues. Manuele (2008) writes that "the quality of incident investigation is one of the principal markers in evaluating an organization's safety culture," and "condoning inadequate investigation defines a safety culture problem" (pp. 341-342).

Consider that organizations have not changed their methods to include identifying systemic incident causes (e.g., design, planning, management influences); they have also not changed the way they problem solve to include higher-order controls. This continued focus on lower-order controls (e.g., train, focus on behavior, write procedures) may explain the decline in frequency rate without a similar decline in severity rates.

In his studies of incident causality reports, Manuele (2006) concludes that:

> •causal factors for low-probability/high-consequence events are seldom represented in the analytical data on accidents that occur frequently (ergonomics being the likely exception); and
> •many incidents resulting in serious injury are unique and singular events, having multiple, complex causal factors that may have technical, operational systems or cultural origins. (p. 33)

Therefore, it may be that if organizations tend to solve OSH issues with lower-order controls they will impact frequency but not severity.

The search for system deficiencies during any incident analysis should reveal management and systemic shortcomings that, if corrected, will have positive effects not only on the specific incident being analyzed but also on broader organizational safety and health. This is because the organization is learning more about these shortcomings and correcting issues using higher-order solutions that can improve systems. Lower-order controls can affect individual and group behavior for a given time, but can mask management and systemic deficiencies that will eventually result in an infrequent yet severe incident. The present study brings attention to the ease with which SH&E professionals utilize lower-order controls. As Kletz (2006) explains:

> Learning from experience is a lantern on the stern, illuminating the hazards the ship has passed through. It is essential to do so as we may come the same way again. However, we should also have a lantern on the bow so that we can see the hazards that lie ahead. (pp. 74-75)

The aim of this research was to evaluate whether recent national focuses on PTD and utilization of the hierarchy of controls have caused a change in the way organizations are problem solving during incident investigation and analysis with respect to the identification of root causes and corrective actions. The two specific null hypotheses are:

Hypothesis 1: Accident causes, categorized as latent and active failures, identified through incident investigations have not changed over time.

Hypothesis 2: Solutions to OSH issues, categorized by the hierarchy of controls, identified through incident investigations have not changed over time.

Other researchers have evaluated the hierarchy of controls in safety problem solving. Amyotte, MacDonald and Khan (2011) analyzed 63 CSB investigations and classified recommended control measures. They found that 36% of total overall examples recommended inherent safety (minimization, substitution, moderation, simplification); 8% recommended passive, engineered safety; 14% active engineered safety; and 42% procedural safety.

In the context of healthcare safety, Card, Ward and Clarkson (2012) conducted a literature review focused on problem solving in healthcare. In a review of 60 articles, they found that risk control solutions that proposed elimination or substitution were recommended 1.5% of the time, engineering controls 18.4%, and administrative and PPE 80.1% of the time.

What is learned and recommended from incident investigations ultimately determines their effectiveness.

Methods

The year 2007 was chosen as the demarcation point. Organizations that have kept old incident investigation reports and that agreed to participate in the study were asked to send the researcher a uniform number of reports from each time period

Operational Definitions for Active & Latent Failures

As defined by Reason (2000):

Active failures are the unsafe acts committed by people who are in direct contact with the system. They take a variety of forms: slips, lapses, fumbles, mistakes and procedural violations. Active failures have a direct and usually short-lived impact on the integrity of the defenses.

Latent conditions are the inevitable "resident pathogens" within the system. They arise from decisions made by designers, builders, procedure writers and top-level management. Such decisions may be mistaken, but they need not be. All such strategic decisions have the potential for introducing pathogens into the system. Latent conditions have two kinds of adverse effect: they can translate into error-provoking conditions within the local workplace (e.g., time pressure, understaffing, inadequate equipment, fatigue, inexperience) and they can create long-lasting holes or weaknesses in the defenses (e.g., untrustworthy alarms and indicators, unworkable procedures, design and construction deficiencies). Latent conditions—as the term suggests—may lie dormant within the system for many years before they combine with active failures and local triggers to create an accident opportunity. Unlike active failures, whose specific forms are often hard to foresee, latent conditions can be identified and remedied before an adverse event occurs. Understanding this leads to proactive rather than reactive risk management.

Note. *From "Human Error: Models and Management," by J. Reason, 2000,* British Medical Journal, 320, *pp. 768-770.*

(2008 to present; and 2006 and earlier). Contacts were told that the reports must contain, at minimum, the list of incident causes and corrective actions. The research did not directly involve human subjects as participants. However, the incident investigation forms sent to the researchers could contain personal information. So, the participating organizations were directed to remove any personal identifiers of injured employees, supervisors and other employee names contained within the reports before sending them.

Sampling Frame

ASSE provided support to engage participants by sending the research summary and request to the practice specialty administrators requesting that they distribute and encourage their membership to participate. The ASSE LinkedIn site was utilized to communicate the research and solicit participants. The main reason given for nonparticipation was that the manager or legal department did not want incident investigation information shared. The goal was to obtain as many incident reports as possible and companies were not randomly selected.

Content Analysis

Content analysis is a general method for studying artifacts. In this research, the artifacts studied were the incident reports. Content analysis usually quantifies information by means of a technique called coding. The researchers make a judgment about content according to a set of agreed on dimensions. The dimensions employed were operational definitions of active and latent failures, and the definitions of the control measures in the hierarchy of controls.

Before judging the content, researchers must first agree on a common set of dimensions and specific definitions of the evidence to be sought. In this research, the identified incident causes were classified as either active or latent failures according to Reason's (2000) definitions (see "Operational Definitions for Transfer Active & Latent Failure" sidebar). The "Operational Definitions for the Hierarchy of Controls" sidebar content comes from various sources.

Establishing these operational definitions, improves the reliability and validity of the content analyses and coding determinations. Coding requires more than one judge so that the resulting data reflect a more objective view of the artifact. Two raters (the authors) identified the categorical dimensions to strengthen reliability of the results. When disagreement occurred, both researchers reanalyzed the reports and discussed their findings and application of the operational definitions. This was performed until agreement was reached.

Results

The research used 249 valid investigation reports from seven organizations; three of the organizations' incident investigations were found on the Internet; four sent copies of their reports. The reports addressed various events and exposures. Table 1 presents a summary.

Active & Latent Failures

Chi-square analysis (which tests relationships between categorical variables) reveal that incident causes, categorized as active failures, identified through incident investigations have not changed over time (p = .085). However, the p-value approaches the significant level of .05 and analysis of the raw data in Table 2 (p. 38) shows that identifying active failures as causal factors is decreasing. Likewise, the relationship between time periods and the identification of latent failures was not significant (p = .235); however there is a slight increase in the percent that latent failures are being identified in accident investigations.

Solutions

The use of hazard elimination as a solution to OSH issues identified through incident investigations has increased between the two time periods (p = .004). In the 2006-and-earlier data set, 2% of the solutions were identified as elimination of hazards and risks, compared to almost 11% in reports for 2008 to present. Investigators in these organizations offer elimination of hazards and risks as a potential solution identified through the investigation process. Relationships between the two time periods and substitution as a control were not significant (p = .267); the same as with engineering controls (p = .938).

Overall, for higher-order controls, no difference was found between the two time periods (p = .181). Comparisons of the higher-order controls are detailed in Table 3 (p. 38). The lower-order controls are compared in Table 4 (p. 38). None of the relationships were statistically significant: warning (p = .430); administrative controls (p = .201); and PPE (p = .144). Overall, for lower-order controls, no difference was found between the two time periods (p = .395). However, the focus on administrative controls as a solution is interesting and worth noting. In 87.55% of all the investigations reviewed, an administrative control was recommended.

Relationship Between Failures & Solutions

If an active failure occurs, using a lower-order control might make sense. Conversely, if a latent failure is identified, why would one limit the solution to a lower-order control? There was a relationship between the identification of a latent failure and recommending engineering controls (p = .027). When latent failures were identified, investigators were more likely to recommend engineering controls.

Overall, for higher-order controls, this generally held true as well (p = .058), meaning that when a latent failure was identified, investigators were more likely to recommend a higher-order control than a lower-order control. These results make sense since those failures are within the system and out of the control of the worker—why address them with lower-order controls? This held true with our data; an inverse relationship was found between the identification of a latent failure and the utilization of administrative controls (p = .041). Administrative controls were less likely to be specified when latent failures where identified.

Similarly with active failures, when an active failure was identified as a deficiency, investigations specified administrative controls (p = .019), and lower-order controls more often than expected (p = .058).

Analysis by Organization & Injury Type

Chi-square analyses determined relationships within each participating organization and overall by type of injury for the top five ("Operational Definitions for Active and Latent Failure" sidebar). One company showed changes in identifying more latent failures compared to active failures in the later time period (p = .024); although not statistically significant, the company also is beginning to solve OSH problems utilizing higher-order controls (p = .064). Relationships by type of injury were not significant.

Multiple or Single Failures & Solutions

In the dataset, the organizations were focused largely on single causes and single solutions; on average each investigation identified 1.05 failures and 1.3 solutions. Various literature indicates that incidents have multiple causes, and multiple solutions and learning opportunities (Behm & Schneller, 2013; Fahlbruch & Schöbel, 2011; Kletz, 2006; Schröder-Hinrichs, Baldauf & Ghirxi, 2011;). Previous research (Behm & Schneller, 2013) found 6.6 causes and factors indentified per incident during a thorough research process compared to 1.2 causes and factors identified by the case study organization.

Operational Definitions for the Hierarchy of Controls

1) Elimination. Removal of the hazard and thus the risk through the design and redesign processes.
2) Substitution. Replacing the hazard with an alternative with less risk. Substitute a less-hazardous material or reduce the system energy (e.g., lower the force, amperage, pressure, temperature) (OHSAS 18002). The consensus is that this control is permanent to the work system, tools, etc., and to be differentiated from administrative controls, which, ideally, are temporary in nature or focus on procedures, human elements, etc.
3) Engineering. Safety devices are incorporated into the system with the intention of preventing worker access to a hazard. They separate workers from hazardous energy and deter worker error (Manuele, 2008). These are physical in nature.
4) Warning. Safety signs, hazardous area markings, photoluminescent signs, markings for pedestrian walkways, warning sirens/lights, alarms (OHSAS 18002).
5) Administrative. Training, job planning, rotating employees, schedule changes, changes to work procedures, implementation of work area protection (e.g., temporary barricades) and similar measures (ANSI Z10); safety procedures, equipment inspections, access controls, safe system of working, tagging and work permits (OHSAS 18002).
6) PPE. Use of safety glasses, goggles, face shields, respirators, fall protection devices, welding screens, safety shoes, gloves, hearing protection, barrier creams, and other gear and apparatuses to minimize contact with a hazard.

Table 1

Type of Event or Exposure

	N	%
Fall	46	18.5
Cut/laceration	37	14.9
Strain/sprain	35	14.0
Struck by	30	12.0
Caught between	12	4.8
Subtotal: Top 5	**160**	**64.2**
Other/misc.	89	35.8
Total	249	100.0

Table 1 presents a summary of events covered in the incident investgation reports reviewed.

Table 2
Active & Latent Failures

	No. of investigations[a]	Active failures	%	Latent failures	%
2006 and earlier	139	55	39.57	90	64.75
2008 to present	110	32	29.09	79	71.82
Totals	249	87	34.94	169	67.87

Note. *[a]The number of investigations does not necessarily reflect the sum of each row if both failure types were identified in the same investigation.*

Table 3
Higher-Order Controls

	No. of investigations	Eliminate	%	Substitution	%	Engineering	%	Total higher order controls[a]	%
2006 and earlier	139	3	2.16	6	4.32	11	7.91	19	13.67
2008 to present	110	12	10.91	2	1.82	9	8.18	22	20.00
Totals	249	15	6.02	8	3.21	20	8.03	41	16.47

Note. *[a]The totals do not necessarily reflect the sum of each row if two or more controls were identified in the same investigation.*

Table 4
Lower-Order Controls

	No. of investigations	Warn	%	Administrative	%	PPE	%	Total lower order controls[a]	%
2006 and earlier	139	1	0.72	125	89.93	2	1.44	126	90.65
2008 to present	110	2	1.82	93	84.55	5	4.55	96	87.27
Totals	249	3	1.20	218	87.55	7	2.81	222	89.16

Table 2 shows how identifying active failures as causal factors is decreasing.

Table 3 details comparisons of the higher-order controls.

Table 4 details comparisons of lower-order controls.

Schröder-Hinrichs, et al. (2011), reviewed maritime incident reports and found that organizational factors were not identified to the extent expected but rather contributing factors at the sharp end (worker level) are overrepresented. Recommendations by Kletz (2002, 2006) about exploring beyond the immediate causes and looking into the system, and investigators not seeking causes beyond what they can immediately control are important here.

Discussion

Elimination was the only control for which a statistically significant change occurred between the two time periods; elimination of the hazard as a recommendation increased over time. The authors observed a slight increase in the recommendation of higher-order controls over time. While that is good for decision making and some change is noticed, investigators are still overwhelmingly recommending administrative controls (87.55%); 7 of 8 investigations listed an administrative control as a solution. Is that percentage too high? Or, should the higher-order controls at least be recommended more often to reveal their advantages and what could be achieved?

In the later time period, higher-order controls were listed as a recommendation 20% of the time. Is that where we want to be? The authors' research did not assess whether a recommended solution was valid or feasible; furthermore, the authors did not determine whether any of the solutions were actually implemented. The research is descriptive.

However, for some incidents, the authors did question why a higher-order control was not included. In one example, an employee was using a ladder to access an electrical panel and slipped from the ladder and hurt his forearm. The identified cause was an active failure of not descending the ladder properly and the only listed solution was to train the employee in the proper use of a ladder. It would seem that questioning why the electrical panel is at a height where a ladder is necessary should be listed in the investigation. It may not be possible to impact this particular event and location. However, by not including it, an opportunity for organizational learning about possible future design and redesign changes has not been documented and, thus, is lost.

In similar analyses, Lundberg, Rollenhagen and Hollnagel (2010) found that "many investigations stop the analysis at the level of 'preventable causes,' the level where remedies that were currently practical to implement could be found." They contend that this "limits the usefulness of using investigations to get a view on the 'big picture' of causes of accidents as a basis for further remedial actions."

One also must consider whether safety professionals and the safety function are in a position (organizationally speaking) to realistically and effectively utilize higher-order controls. Does the safety function work with the people who can implement higher-order controls (e.g., engineers, architects, designers, senior-level executives, operations managers and planners)?

Perhaps safety professionals are stuck in an administrative control mind-set. Training, updating procedures and policies, and employee behavior are components that a safety professional can easily change and are likely within their sphere of influence. Is the safety profession stuck at the sharp end? Getting involved in process changes, design meetings and activities during which higher-order controls can be recommended and more realistically implemented require that safety professionals be invited to those meetings. Perhaps recommendations in an incident investigation are more closely aligned with their sphere of influence than the hierarchy of controls.

However, the true causes and solutions must be documented and communicated even if they are long-term and organizational in nature. The organizational view of the safety professional's role must evolve and be upgraded. Figure 1 sets forth a proposed relationship between the ability to utilize higher-order controls based on the life cycle of a product, process, service or technology.

Consider the example of a new facility. If the safety professional's knowledge is brought to the decision-making process early (e.g., idea generation, design phase), more opportunity exists to affect hazards and risk through elimination, substitution and engineering controls. If SH&E professionals are brought in a month before facility start-up to conduct a preoccupancy audit, the building and its components are already specified and installed. How feasible is it to eliminate or substitute for a hazard at that point? Engineering controls now become expensive retrofits.

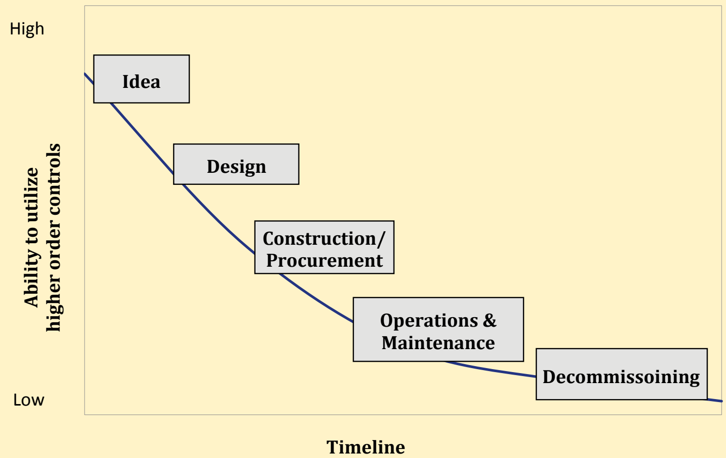
Recall the previous example in which a ladder was needed to access an electrical panel. Perhaps the best a safety professional can do at this point is warn, train, write procedures and implement other lower-order controls. The same can be said for what the authors observed during this research and aligns with Kletz's (2006) observation. However, if organizations can recognize this limitation as truly affecting site safety, then it should create upstream opportunities for safety professionals to be involved with activities as is being outlined in NIOSH's PTD initiative.

The efficacy of implementing the hierarchy of controls is limited by the timing of hazard recognition. If a safe design program is absent and/or if the safety function is viewed as compliance only or line-level technician only, no hazard recognition will occur until the operation begins and the safety function commences its responsibilities.

Safety professionals should evaluate where and when they are conducting their work. It is hoped that safety professionals can share this research with their managers to better anticipate hazards and risks (rather than simply recognizing them after the fact) and better utilize the hierarchy of controls. Management must ensure that safety professionals are in an effective position to conduct their work.

Figure 1

Ability to Utilize Higher Order Controls



Note. *Proposed relationship between the ability to effectively utilize higher order controls and the timeline of a product, process, technology or service. Adapted from "Construction Project Safety Planning," by R. Szymberski, 1997,* TAPPI Journal, 80*(11), pp. 69-74.*

Figure 1 shows a proposed relationship between the ability to utilize higher-order controls based on the life cycle of the product, process, service or technology.

Limitations

The lack of participation by more and a broader array of organizations is a limitation to the research. However, the methodology and results will allow safety professionals and their respective organizations to begin discussions about analyzing their own OSH problem solving and consider how to best utilize the hierarchy of controls. The research also did not focus on the particular investigation model each organization utilizes, which may affect individual organizations' results. The authors did not analyze the job title of the person conducting the investigation, which would likely influence the outcome as well.

Conclusions

The two null hypotheses have failed to be rejected. Incident causes, categorized as latent and active failures, identified through incident investigations have not changed over time. Solutions to OSH issues, categorized by the hierarchy of controls, identified through incident investigations also have not changed. The results show that risk-reduction recommendations in incident investigations are shifting slightly to include additional higher-order controls. Perhaps the NIOSH PTD initiative and a focus on ANSI Z10 and the hierarchy of controls are having some effect on problem solving. However, the effect is not significant. Moreover, the authors conclude that these results suggest that safety professionals may be stuck in an administrative control rut, fixated on identifying single causes close to the work operation. Investigators need to look more holistically at the work system.

When investigators look beyond the immediate failures and into the system they will initiate true organizational learning.

Safety professionals must be in a position to effectively create system changes. Where the safety function operates within its respective organizations and the timing of its involvement may be a limiting factor to the effective utilization of the hierarchy of controls. This may explain the administrative control mind-set.

On the other hand, safety professionals must be ready to interact with engineers, executives, designers and planners. If the safety function were to be involved in the design phase review of a new building and seven of eight recommended controls were administrative in nature (as found in this study), this would be a waste of resources. Why get involved in upstream safe design activities if fixated on applying downstream measures?

All organizations should analyze what types of failures and subsequent solutions they are identifying. This should not be limited to incident investigations, but should include all hazard identification methods, such as audit processes and safety committees. If an organization analyzes in this manner, it has a baseline from which to strive for improvement in the recommendation and utilization of the hierarchy of controls. It would also be interesting if similar industries (e.g., a trade association) could analyze their deficiencies and controls to find common solutions higher up the hierarchy of controls, which in turn could impact the supply chain, equipment manufacturers, etc. Only then can we realize the innovation purported by Culvenor (2006).

Organizations should seek to identify and evaluate the various and multiple failures and subsequent solutions during incident investigations. When investigators look beyond the immediate failures and into the system they will initiate true organizational learning and be impactful for risk reduction on both the micro and macro scales. It is hoped that this research will serve as a benchmark for individual organizations and for future research endeavors. **PS**

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