MOVING BEYOND T
Measuring & Monitoring Sa With High-Energy Control

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A ADVANCEMENT OF SAFETY requires a standardized method of measuring and communicating safety performance. A common safety metric enables professionals across industries to compare outcomes, assess trends and make strategic decisions. Although never explicitly intended as a comparative safety metric, total recordable incident rate (TRIR) has been the dominant indicator of safety performance for more than 50 years (Hallowell et al., 2021; U.S. Bureau of Labor Statistics, 2019). Defined simply as the rate at which a company experiences an OSHA-recordable incident scaled per 200,000 work hours, TRIR has been used to make important business decisions ranging from the prequalification of contractors to annual performance incentives (Karakhan, 2017; Lingard et al., 2017; Lofquist, 2010; Wilbanks, 2018). TRIR has become ubiquitous, in part because it is simple, standardized and easy to communicate. However, recent research has shown that TRIR has serious limitations that impede strategic decision-making and long-term improvement (Hallowell et al., 2021; Korman, 2022). This leaves the safety community and other business professionals asking, "If not TRIR, then what?"

A common answer to this question is leading indicators. However, despite their strengths, safety leading indicators have some limitations that prevent them from being a wholesale solution. First, safety professionals still do not agree on a single definition of a leading indicator, and the term is used so broadly that it can mean anything that is not injury rates (lagging indicators). Even with the more accepted academic definition (i.e., measures of the activities performed to prevent injuries), leading indicators are not yet benchmarkable because they are not consistently applied across the industry. That is, companies measure different aspects of the safety system in different ways, making the resultant numbers incomparable among companies. Although safety leading indicators are likely to be an important part of a future solution once standardized, safety professionals still need a method of safety assessment that 1. enables consistent and objective assessment of the safety related to working conditions at any point in time, and 2. statistically explains the relationships between leading indicator activities (inputs) and long-term injury rates (outputs).

In this article, high-energy control assessment (HECA) is introduced and explored as a new way of monitoring and measuring safety performance. By combining the latest science in high-energy controls with principles of human and organizational performance, HECA is underpinned by science, statistically valid, focused on serious injuries and fatalities (SIF), and representative of a modern understanding of safety as the presence of safeguards rather than the absence of injuries. The authors introduce HECA as an initial attempt to close the gap between modern safety science and principles (what we say), and current methods of measuring, monitoring and communicating safety (what we do).

KEY TAKEAWAYS

- The prevailing method of measuring safety performance, total recordable injury rate, is statistically and philosophically flawed.
- High-energy control assessment (HECA) is introduced as a new method to monitor the presence of safeguards against critical hazards (e.g., capacity).
- HECA is built on the philosophy that all life-threatening (high-energy) hazards should have an adequate safeguard (direct control).
- Methods to assess the energy magnitude and the presence of a direct control objectively and consistently are presented along with a case example.
- HECA is positioned as a performance monitoring method to continuously track and manage safety. HECA may generate sufficient volumes of data to inform reliable data-driven strategic decision-making.

Background

To illustrate the need for a new method of safety performance assessment, HECA is juxtaposed with the prevailing method of safety performance measurement: TRIR. Because TRIR is pervasive and ingrained within the industry, it is critical to explore its strengths and weaknesses before introducing alternative assessment strategies. The authors' position is that any alternative safety metric must capitalize on the strengths of TRIR while addressing its fundamental weaknesses.

The quality of any performance metric (safety or otherwise) can be judged against the six primary criteria in Table 1. These criteria include those based on direct evidence (objective, valid and predictive) and on judgment and values (clear, important and actionable). To provide an honest and holistic assessment of TRIR, the authors evaluate it empirically and logically against each of the six criteria. Although the focus is on TRIR because it is the most dominant safety performance metric, most assessments in this article apply similarly to any lagging indicator that is based on injury rates.

1. Objective: TRIR is objective because it is based on direct observation. TRIR is based simply on a count of recordable injuries over time. Although there are well-documented issues

TRIR
afety Performance Assessments

with underreporting, case management and data manipulation (Pedersen et al., 2012), there is typically only one definition of what makes an incident recordable in a geographical region (e.g., OSHA-recordable injury in the U.S.).

2. Valid: TRIR is not valid because it is not statistically stable. Although never mandated by OSHA for business use, TRIR is often used to make direct comparisons among businesses, projects and teams often over a relatively short time. When applied in this way, TRIR loses statistical validity. A metric is statistically valid if it is based on sufficient volumes of consistent data within reasonable time frames to allow acceptable uncertainty estimations and statistical precision (Kotek et al., 2018; Oguz Erkal, 2022). An analysis of more than 3 trillion worker hours revealed that the occurrence of recordable injuries is almost entirely random and that more than hundreds of millions of worker hours are needed before TRIR carries statistical meaning (Hallowell et al., 2021). Therefore, in almost any practical scenario, it is statistically problematic to use TRIR to inform business decisions.

3. Predictive: TRIR is not predictive because TRIR of the past is not indicative of TRIR (or fatalities) in the future. In addition to statistical instability, TRIR of the past does not provide predictive information about TRIR of the future (Hallowell et al., 2021). Per this research, TRIR has no statistical relationship to SIFs, meaning that recordable injuries should not be used as a proxy or warning sign of something more serious to come.

4. Clear: TRIR is clear because it is easy to understand and communicate. Perhaps the greatest strength of TRIR is that it is easy to understand and communicate. Since OSHA-recordable injuries are based on a government mandated definition of a recordable injury, one consistent definition is used across companies, industries and geographies.

5. Actionable: TRIR is not actionable because it does not support proactive behavior or strategic decisions. Since TRIR only represents rare, random and historical incidents, it does not provide useful information about underlying patterns of why injuries occur or what contributes to success. At its best, a spike in TRIR motivates organizations to put more time and energy into the safety system without a targeted strategy.

6. Important: TRIR is not important because it is not aligned with emergent safety principles or a focus on SIF. Although not explicitly stated in the definition of TRIR, using injury rates to communicate safety performance is based on the implicit premise that safety is the absence of injuries. That is, TRIR is implicitly based on the idea that a worker hour

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TABLE 1
QUALITIES OF A STRONG METRIC

Criterion	Definition	Reference
Objective	The metric is based on observations that are minimally subject to cognitive biases.	Johansen and Rausand, 2014; Kotek et al., 2018; Leveson, 2015; Taaffe et al., 2014
Valid	The data required for the metric can be generated in sufficient volume to produce statistically significant trends.	Kotek et al., 2018; NORSOK, 2008
Predictive	The historical trends in the metric provide information on the probability of future trends.	Alexander et al., 2017; Esmaeili et al., 2015; Goh and Chua, 2013; Hallowell et al., 2017; Hinze et al., 2013; Salkind, 2010; Tixier et al., 2016
Clear	The metric is easy to understand and practical to communicate.	Johansen and Rausand, 2014; Kotek et al., 2018; Leveson, 2015; NORSOK, 2008; Taaffe et al., 2014
Actionable	The metric provides information that may prompt interventions and strategic planning.	Johansen and Rausand, 2014; Kotek et al., 2018; NORSOK, 2008; Taaffe et al., 2014
Important	The metric reports information related to an organization's strategic vision and goals.	Johansen and Rausand, 2014; Kotek et al., 2018; Leveson, 2015; Taaffe et al., 2014

FIGURE 1
HECA METRIC STRUCTURE

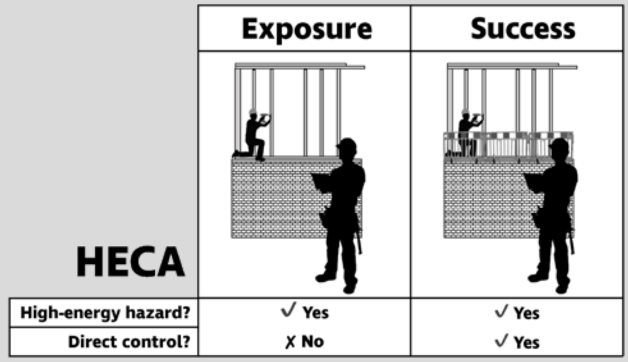
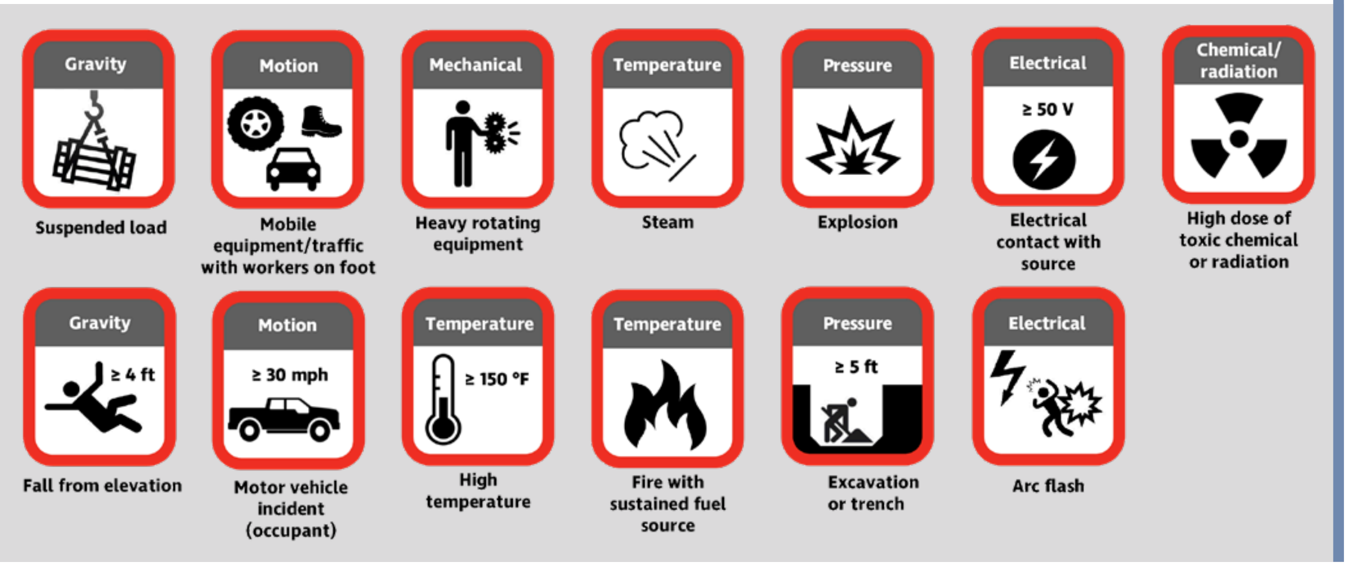


FIGURE 2
EXAMPLE HIGH-ENERGY HAZARDS



without a recordable injury was safe and a worker hour with a recordable injury is unsafe. However, not every worker hour without an injury involves safe work; sometimes work is performed unsafely, and the organization is simply lucky that an injury did not occur (Conklin, 2019). Instead, safety has been reimagined as the presence of safeguards (capacity), rather than the absence of injuries (Hollnagel et al., 2015; Lofquist, 2010). Thus, TRIR and other injury rates are antithetical to modern views of safety.

In addition to misalignment with contemporary safety principles, TRIR is not focused on SIFs. Since TRIR, by definition, includes a large spectrum of incident severities, from a two-stitch cut on the finger to a fatality, it is reasonable to estimate that SIFs account for a small proportion of recordable incidents. Because TRIR does not include exclusive information about SIFs and is not predictive of future SIFs, it is logical to conclude that TRIR does not have much utility for preventing SIFs. Although it may be tempting to suggest using fatality rates to address this concern, note that fatality rates are even less statistically stable than TRIR because fatalities are equally random and even rarer than recordables.

Based on the severe limitations of TRIR, there is a need for a new method of assessing safety performance that is scientifically valid and aligned with modern safety philosophies and priorities. To this end, the authors introduce and explore HECA as an intentionally created method of safety performance monitoring that may complement other forms of safety performance assessment.

What Is HECA?

HECA is defined as the percentage of high-energy hazards with a corresponding direct control. HECA is built on the concept that safety performance is best measured as the control of high-energy hazards. Structurally, HECA is binary because every condition observation is modeled only as success (the high-energy hazard has a corresponding direct control) or exposure (the high-energy hazard does not have a corresponding direct control), as shown in Figure 1 (p. 27). The formula to calculate HECA is given here.

The total number of HECA observations:

$$Total = success + exposure$$

where success is the number of high-energy hazards with a corresponding direct control and exposure is the total number of high-energy hazards without a corresponding direct control.

Since the total number of high-energy hazards is equal to success plus exposure, HECA may be expressed as a ratio of success to total number of assessments.

HECA:

$$HECA = \frac{Success}{Total}$$

Although the computation of HECA is simple, the challenge in applying HECA is a consistent application of definitions of a high-energy hazard and direct controls.

What Is a High-Energy Hazard?

The first step in HECA is to identify all high-energy hazards faced by a specific work crew at the time of observation. The term “high-energy” is based on research that shows that the severity of an injury is directly related to the magnitude of physical energy associated with a hazard (Alexander et al., 2017). For example, a heavier object higher off the ground has more potential for serious harm than a lighter object lower to the ground. Specifically, Hallowell et al. (2017) found that hazards with fewer than 500 joules of energy are most likely to cause a first aid injury; hazards with between 500 and 1,500 joules of energy are most likely to cause a medical case injury; and hazards with more than 1,500 joules of physical energy are most likely to cause a serious injury or fatality (Hallowell et al., 2017). Therefore, the term high-energy is used to describe hazards with more than 1,500 joules of physical energy because the most likely result of a contact between a human and this energy source is an SIF. Put simply, high-energy hazards are the life-threatening hazards.

High energy was selected as a key component of HECA to encourage a focus on SIF prevention and to ground the assessment in the latest scientific knowledge. Although practitioners have often focused on discussing the worst possible outcome

FIGURE 3
PIPE SHACK INSTALLATION CASE HAZARD IDENTIFICATION

This table includes all energy sources (hazards) identified by the observer. When the energy computations indicated that the energy magnitude associated with a hazard was less than 1500 joules, the hazard was marked as low energy.

Hazard ID	Hazard name	Energy source	High-energy?
H1	Suspended load (falling)	Gravity	Yes
H2	Elevated pipe	Gravity	Yes
H3	Side boom (tipping)	Gravity	Yes
H4	Side boom (tracking)	Motion	Yes
H5	Swinging load	Motion	Yes
H6	Vehicular traffic	Motion	Yes
H7	Cable and pulley	Mechanical	Yes
H8	Power lines	Electrical	Yes
H9	Compressed gas	Pressure	Yes
L1	Uneven ground	Gravity	No
L2	Construction noise	Sound	No
L3	Sun exposure	Radiation	No
L4	Insects	Biological	No
L5	Pesticides	Chemical	No
L6	Pipe surface temperature	Temperature	No

associated with a hazard, this can be counterproductive because an SIF is always remotely possible. Instead, it is more productive to discuss the most likely outcome associated with a hazard. Using the concept of high energy refocuses attention on hazards that are most likely to cause an SIF.

Although computing the magnitude of energy associated with an energy source is relatively simple for some energy types (e.g., gravity, motion), others are much more complex (e.g., mechanical, pressure). To enable field assessments, the 13 icons in Figure 2 were created by the Edison Electric Institute (Hallowell, 2020). These high-energy icons represent approximately 85% of all high-energy hazards documented in the literature as primary causes of SIFs (Hallowell et al., 2017). Although the high-energy icons enable a more practical analysis, not all high-energy hazards lend themselves to icons. For example, while some dropped tools may be high energy if the tool is high and heavy enough, many dropped tool scenarios are not high energy. Therefore, computations of energy magnitude may be required for some hazards to ensure a complete assessment. Such additional computations may be warranted due to various task- or context-based energy sources such as calculating the energy contained in equipment operations (e.g., side boom tracking and tipping) or consulting with an industrial hygienist for determining threshold exposures to toxic chemicals or radiation (Electric Power Research Institute, 2019). The high-energy icons in Figure 2 can be used to simplify the energy assessment process; however, if an icon does not apply, it is always reasonable to calculate the energy magnitude using the methods described in Hallowell et al. (2017).

What Is a Direct Control?

The second step in measuring HECA involves determining whether a direct control exists for each high-energy hazard observed. Aligning with the idea of safety as the presence of safeguards, HECA is built on the notion that every high-energy hazard should have a corresponding control that ensures that an SIF is no longer reasonably probable. Here, the term "direct control" is used to refer to a control that meets the minimum standards offered by the Edison Electric Institute (Hallowell, 2020). Although there are levels within the hierarchy of controls (i.e., elimination, substitution, engineering, administrative, PPE) and different types of controls documented in literature (i.e., absolute, mitigative, preventative), the authors intentionally use a definition for direct control that is binary (i.e., a control is or is not a direct control). One consistent definition promotes clarity, simplicity and practicality, and allows the community to move forward with a scientific definition, which is critical for the external validity.

Hallowell (2023) offers a precise and strategically designed definition of a direct control that aligns with both energy-based safety and human and organizational performance principles.

To qualify as a direct control, a control must meet all three of the following criteria:

1. Targeted to the high-energy hazard. The control must be specifically designed and intentionally used to address the high energy of concern. Examples of targeted controls include fall arrest systems for work at height, machine guards for rotating equipment and engineered excavation support systems.

2. Effectively mitigates to the high-energy hazard when installed, verified and used properly. A direct control must either eliminate the energy or mitigate the energy exposure to below the 1,500-joule threshold. An example of a direct control that eliminates the energy exposure is the de-energization, verification and lockout/tagout for electrical energy. An example of a control that reduces but does not eliminate the energy is a self-retracting fall arrest system.

A control is only considered present when it is installed, verified and used properly. If the control is not installed properly, inspected on schedule, maintained regularly or is misused, the control is considered absent. For example, a personal fall arrest system must be properly installed to an engineered anchor point, inspected, maintained on the prescribed schedule and worn properly on the body to be considered present.

3. Effective even if there is unintentional human error during the work (unrelated to the installation of the control). Controls are not considered adequate to protect against life-threatening hazards if they require workers to be perfect when using them. Given enough time, the probability that a worker will make an unintentional error is 100%. Thus, it is not *if* a worker will make a mistake, it is *when*. The controls against high-energy hazards must be functional even when someone makes a mistake during work. For example, situational awareness, signage and training are not considered direct controls because they are all vulnerable to human error. However, engineered barricades, de-energized electrical systems and some highly specialized PPE may be direct controls because they are effective even if a worker makes a mistake.

Importantly, all controls are vulnerable to human error during their installation. Therefore, criterion two includes the language "installed," "verified" and "used properly" and criterion three includes the language "unrelated to the installation of the control."

HECA Case Example

A case example is provided to illustrate HECA in a practical scenario. This case describes a pipe shack lifting operation being performed by one crew. The operation involves lifting and installing a pipe shack over a pipe supported by a temporary structure using a crane. The work takes place within a rural site on a sunny day that is approximately 60 °F. The work location is in proximity to a field or farm, power lines and a temporary site road.

Identification of Hazards

The energy sources (hazards) identified by the observer are shown in Figure 3 (p. 29). Nine high-energy hazards and six low-energy hazards were identified. Low-energy hazards included sun exposure (below 70 °F), insects and pesticide exposure from adjacent farms, noise exposure to typical machinery operations, uneven ground and pipe surface temperature. The high-energy hazards were further evaluated in the HECA assessment as shown in Table 2. When assessing whether a hazard is high energy, the 13 high-energy icons in Figure 2 (p. 28) were used. If the hazard was not represented by an icon, a formal energy computation was performed to determine whether the hazard was high energy (≥ 1,500 joules) or low energy (< 1,500 joules).

Assessment of Direct Controls

A control assessment was performed for each high-energy hazard to determine whether there was a corresponding direct control. For future data analysis and intelligence, the relevant controls (both present and absent) were recorded. The data only represented as-found conditions before any immediate intervention or corrective action was taken in response to the condition assessment. The assessment of each control is shown in Table 2. Note that for all direct controls missing in this example, the only feasible solution identified by the observer was a hard physical barricade, which was not installed in this case.

Although HECA is designed to assess the presence of direct controls only, the authors recognize that such controls might not always be possible or feasible in practice given the resource constraints or available technology. In such cases, controls other than direct controls (e.g., having spotters, specialized training to workers) play a role as a secondary line of defense to reduce the risk of exposure becoming an incident. These instances point to opportunities for innovation where the industry could collaborate to develop direct controls over time.

HECA Evaluation

If a high-energy hazard existed without a direct control, the observation was marked as "exposure." If a high-energy hazard had a corresponding direct control, the observation was marked as "success." The analysis was performed using the hazards as the units of analysis to enable more refined trending, analysis and modeling.

In the case image (Figure 3, p. 29), nine high-energy hazards were identified, five of which had corresponding direct controls. As a result, using the given formula, HECA was calculated to be 5/9, or 56%. This percentage indicates that 56% of the high-energy hazards were controlled by direct controls while 44% were not.

HECA Is Neither Leading nor Lagging; It Is a Method of Monitoring

Safety performance assessments are often categorized as lagging or leading with nothing in between. Typically, measures of injury prevention activities (e.g., frequency of safety observations) are considered input metrics and are categorized as leading indicators. Alternatively, injury rates (e.g., TRIR) are considered outputs of the system and categorized as lagging indicators. Both leading and lagging indicators generally involve measurement where the experiences and observations over an extended time are reduced to a single number. Leading indicators typically involve the total number of times a safety activity was performed, and lagging indicators are represented by the number of injuries, illnesses or other incidents.

HECA is different. It is not a leading indicator because it is not a measure of a safety activity and is a direct consequence of the safety system in place. Also, despite being an output metric, it is also not a lagging indicator because it is not an incident rate. Since HECA is intended to be collected during active work, it represents a consequence of the safety system, but precedes the occurrence of a serious safety incident. Thus, instead of attempting to characterize HECA as leading or lagging, HECA is positioned in the middle from a timeline perspective as a monitoring variable that may moderate or explain the relationship between leading and lagging variables.

In contrast to measuring, monitoring is a method of nearly real-time surveillance to assess and act upon underlying trends over relatively short periods. As an analogy, traffic engineers may measure the success of a transportation system as the number of people moved through the system in a year or decade, but real-time traffic monitoring helps citizens to select the best possible route in a morning commute. Although both measurement and monitoring are important; measurement is summative and reflective, and monitoring is ongoing and supports proactive decision-making. In safety, safety measurement (long-term trends) has largely been explored rather than monitoring (short-term trends).

Monitoring safety conditions may enable regular learning, real-time trending, strategic discussions and mobilization of resources before serious incidents occur. That is, a monitoring variable such as HECA allows an organization to control safety rather than react to historical trends. Like leading and lagging variables, HECA may also be reduced to a meaningful number when aggregated over enough time. However, as will be discussed, observation and analysis of trends in HECA are likely to be more insightful than a single HECA number.

The relationship between leading, monitoring and lagging variables is illustrated in Figure 4.

Operationalizing HECA

Because HECA is based on conditions rather than incidents, HECA may be assessed any time work is performed. To

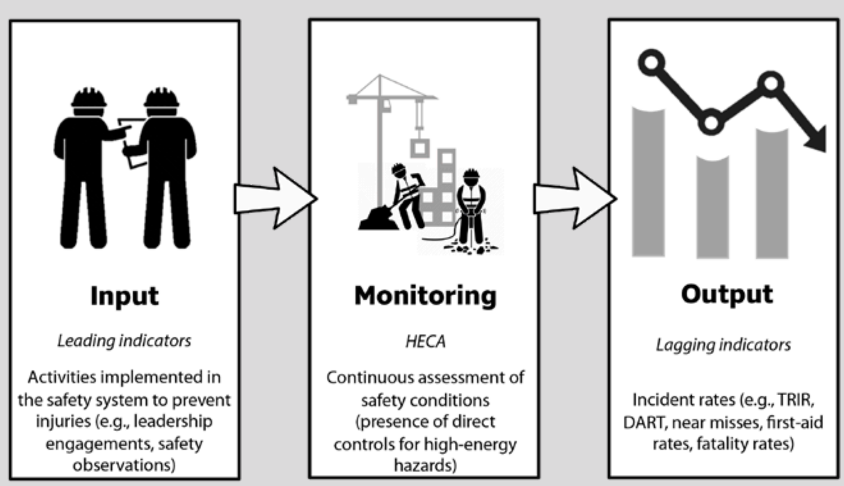
TABLE 2

HECA ASSESSMENT FOR HIGH-ENERGY HAZARDS

Hazard ID	Hazard name	High energy?	Energy assessment	Direct control?	Direct control assessment	HECA evaluation
H1	Suspended load	Yes	Suspended load	No	No energy mitigation, and operation was vulnerable to human error.	Exposure
H2	Supported Pipe	Yes	Suspended load	Yes	Cribbing was engineered and installed properly.	Success
H3	Side boom (tipping)	Yes	Computation of energy magnitude	Yes	Operations were within acceptable equipment limits.	Success
H4	Side boom (tracking)	Yes	Heavy mobile equipment with workers on foot	No	No energy mitigation, and operation was vulnerable to human error.	Exposure
H5	Swinging load	Yes	Computation of energy magnitude	No	No energy mitigation, and operation was vulnerable to human error.	Exposure
H6	Vehicular traffic	Yes	Heavy mobile equipment with workers on foot	No	No energy mitigation, and operation was vulnerable to human error.	Exposure
H7	Cable and pulley	Yes	Computation of energy magnitude	Yes	Cables/rigging were engineered, inspected and used properly.	Success
H8	Power lines	Yes	Electrical energy more than 50V	Yes	The line was de-energized when work was near power lines.	Success
H9	Compressed gas	Yes	Explosion	Yes	Cylinders were engineered, inspected and used properly.	Success

FIGURE 4

HECA TIMELINE



align with a typical safety observation program, HECA was designed to be a short-term assessment of active work. HECA should be measured by a knowledgeable professional during a site visit where the primary purpose is to observe work and determine whether high-energy hazards are adequately controlled. HECA recordkeeping is critical to extracting useful intelligence. Although it may be efficient to record HECA as one number (e.g., the proportion of high-energy hazards with corresponding direct controls), recording the specific observations per high-energy classes enables meaningful trending and strategic decisions. When performing a HECA observation, the following fields are suggested:

- List of high-energy hazards observed (e.g., suspended load, work over 4 ft of height, computation of energy magnitude)
- For each high-energy hazard, was a corresponding direct control observed (yes or no for each high-energy hazard)?
- For each hazard with a direct control, which control was observed (e.g., engineered rigging, fall protection)?
- For each high-energy hazard without a direct control, what control was missing?

For most safety observation programs, collecting these data should not be a large departure from current activities. Although there is more to an effective observation than a controls assessment (e.g., meaningful engagements should be performed with workers), controls for serious hazards should be an integral component. Thus, it should be possible to integrate HECA into traditional safety observation programs once training is provided.

Although some initial thoughts are provided on the operationalization of HECA, much work is yet to be done. The purpose of this article is to simply introduce the concept of HECA for the first time. Future work is planned to better understand HECA in practice and create robust data collection strategies to ensure objective and high-quality data intake.

FIGURE 5
LONG-TERM TRENDING OF HECA FOR HYPOTHETICAL COMPANY A

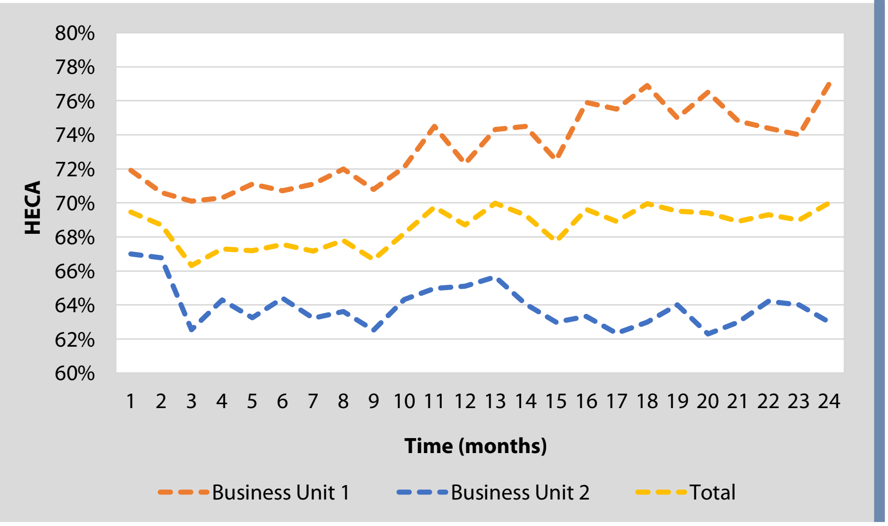
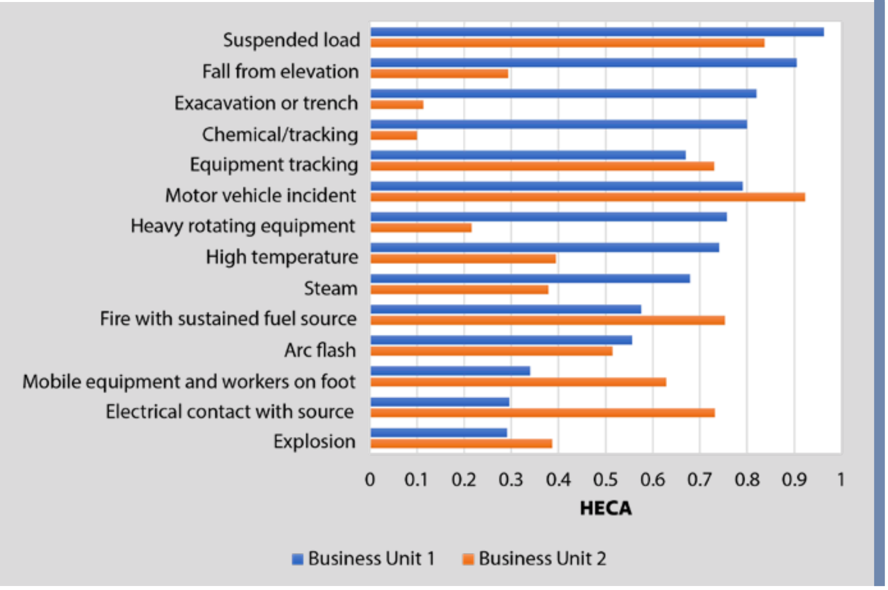


FIGURE 6
EXAMPLE HECA REPORT COMPARING TWO BUSINESS UNITS

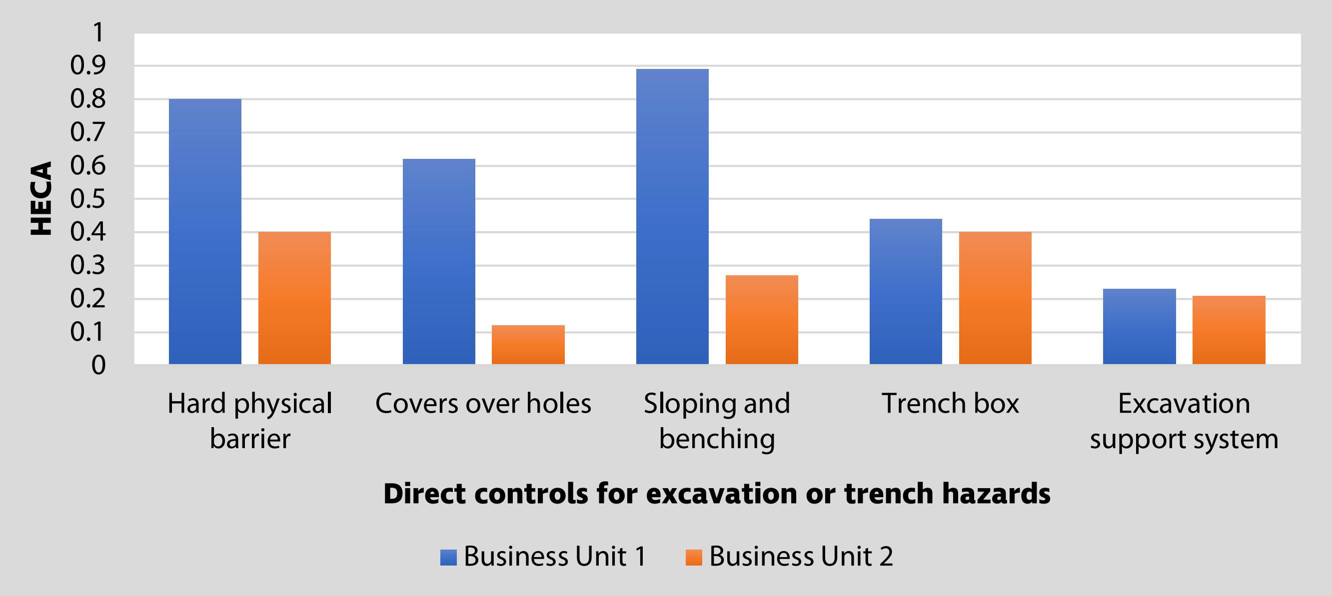


Example Intelligence From HECA

A safety performance assessment is only as useful as the intelligence it provides. Since HECA is based on the actual conditions around a work environment, it supports both tactical response and long-term strategic planning. For example, observing an inadequately controlled high-energy hazard may spur immediate coaching and problem-solving on site that will itself improve the real-time safety performance. Additionally, long-term trends in high-energy hazards and controls may instigate organizational learning, inform research and development activities, and motivate the mobilization of additional resources. Although most safety metrics are only summative in nature, HECA may also support formative assessments that enable continuous improvement.

In the simplest form, HECA may be tracked over time as the proportion of high-energy hazards with corresponding direct controls as monitored in regular condition assessments. Since HECA can be reduced to one single number, it could be used to summarize historical safety performance as a metric that tracks the percentage of high-energy hazards that have corresponding direct controls. The benefit of such information is that it provides insight on the long-term achievement of the primary goal of high-energy control. Figure 5 provides example HECA

FIGURE 7
DIRECT CONTROL COMPARISON OF TWO BUSINESS UNITS



data over a 2-year period for a hypothetical company, Company A, where each monthly HECA value represents the average HECA score for all observed crews of that week in aggregation and for two business units separately. For large companies, a weekly or monthly HECA value collected over sufficient sample size represents the aggregate of hundreds or thousands of crew observations. Such metrics are less vulnerable to random variability, making them more likely to carry statistical stability and predictive power.

When organizations collect data such as the specific high-energy hazards observed and the presence or absence of corresponding controls (see Figure 6 and 7), HECA may be analyzed to answer important questions, define opportunities for learning, and identify needs for targeted safety investments. For any period, HECA data may help to answer questions such as:

•Which high-energy hazards are relatively well controlled, and which are not?

•Which controls are typically present, and which are most commonly missing?

•How do projects or business units compare with respect to controlling specific high-energy hazards?

•To what extent have targeted interventions correlated with improvement in the control of high-energy hazards?

•To what extent do HECA trends predict future performance?

Associated with some of these questions, several graphics were produced for hypothetical Company A with two of its business units to illustrate the potential benefits of using HECA data. These include trends in the control of different high-energy hazards (Figure 6), and the analysis of the presence of specific direct controls (Figure 7) along with comparisons among business units. These analyses reveal important intelligence: Figure 6 shows that Business Unit 1 (BU1) is doing a considerably better job in implementing the direct controls to prevent the exposure to excavation- or trench-related high-energy hazards in comparison to Business Unit 2 (BU2). With this information, Company A could recognize an opportunity for interorganizational learning and shift some of its personnel with such know-how from BU1 to BU2 to advise and improve.

Taking the analysis further, Figure 7 shows the performance of direct controls against high-energy hazards related to excavation or trenches. While BU1 and BU2 have equal performance in implementing trench boxes and excavation support systems, BU1 has a much better performance in ensuring the installation of hard physical barriers, covers over holes and sloping. Company A could decide to effectively focus its efforts toward improving these direct controls.

These are simply a few examples of the types of intelligence one may produce from HECA recordkeeping and analysis. HECA data could yield many other iterations of visualizations and intelligence to show trending over time with high energy and direct control categorical breakdowns, combined with location or work-task-specific parsing as desired.

Evaluation of HECA

As the authors argued, the quality of any metric should be evaluated against the six primary criteria. In the following list, the authors summarize the perceived strengths and weaknesses of HECA and compare it against TRIR, which remains the most prevalent safety metric to date.

1. Objective: HECA is objective based on empirical observation and guided by strict definitions. Definitions and the instructions associated with HECA have little room for cognitive biases when high-energy guidelines are used for the assessment of energy magnitude and the definition of direct control is strictly and concisely applied. HECA simply targets to record the existence of high-energy hazards and associated direct controls. However, initial applications are likely to be based on the judgment of the observer and inevitable assumptions that must be made regarding the conditions on site. Therefore, although HECA has the potential to become an objective metric, it is likely to involve some subjectivity during initial implementation.

2. Valid: HECA is valid because it may be collected at sufficient volume to be statistically stable and precise. HECA could be continuously monitored and measured in great volume, especially if aligned with existing safety observation programs. For example, a company that performs 100 safety observations per month could yield more than 1,000 HECA assessments per year. Thus, in stark contrast to injury rates such as TRIR, HECA can be measured in large volumes making it highly statistically stable.

3. Predictive: It is unclear whether HECA is predictive of future performance because it has yet to be empirically tested. Although it is clear from recent research that TRIR is not predictive, research has yet to be conducted to determine whether HECA has predictive power. Thus, no conclusion can be drawn regarding the predictive nature of HECA.

4. Clear: HECA is moderately easy to understand but will require training to be consistently applied. Because HECA can be simply distilled into one number (i.e., the percentage of high-energy hazards with a corresponding direct control), it can be used as a simple metric. However, it is categorized as only moderately simple because training is required on high-energy and direct controls to ensure that the assessments are performed as designed. If these terms were to be institutionalized to the same extent as the term "recordable," the authors believe that HECA and TRIR would be equally simple.

HECA offers a new, intentionally designed method of assessing safety performance that is aligned with current safety principles and may enable continuous monitoring and strategic decision-making.

5. Important: HECA is important because it is aligned with emergent safety principles and a focus on SIF. Perhaps the greatest strength of HECA is its alignment with contemporary safety thinking. Most modern safety professionals have transitioned away from the notion that safety is the absence of injuries to an understanding that safety is uninterrupted presence of safeguards (capacity). The community is also aligning on the notion that serious injuries and fatality prevention deserve a disproportionately high level of attention (Oguz Erkal et al., 2021). Since HECA directly measures the presence or absence of controls against high-energy hazards that have the likely potential to cause SIF, it is aligned with both a contemporary understanding of safety and the prioritization of SIF. Moreover, HECA supports human performance principles by directly measuring the presence or absence of safeguards (i.e., measuring capacity). Although there may be other forms of capacity that could be assessed, HECA offers a relatively objective method that relies on empirical data. Thus, the authors believe that HECA is a far more important metric than TRIR.

6. Actionable: HECA is actionable because it supports proactive decisions based on continuous data. As a monitoring variable that can be measured in high volume, HECA has the potential to reveal real-time trends that can enable robust learning and proactive decision-making. Specifically, trends in the control of high-energy hazards may highlight resource demands that may otherwise be hidden until serious incidents occur. The ethos of HECA encourages investment in building capacity and resiliency.

In summary, a transition to HECA would involve a trade-off between challenges in objectivity and clarity and improvements in statistical validity, importance and actionability. The authors believe that widespread use of HECA would help to address issues in objectivity and clarity, whereas lagging indicators such as TRIR have little room for improvement.

Conclusions & Recommendations

This article presents a new method for regular monitoring of safety performance, serving as a long-awaited departure from traditional safety performance assessment methods. HECA is strategically positioned as a learning and monitoring metric to complement and improve existing forms of safety performance measurement. Moving forward, the success or failure of HECA will depend on the way it is operationalized, communicated, and to the extent with which it is curated and consistently applied by the industry and research. The next steps in developing HECA for implementation should aim to enhance the rigor and validity of the method, and to provide guidance on how organizations use HECA in business practices. The initial conclusions and recommendations in these areas are provided for consideration.

•**It is critically important to maintain one definition of HECA.** One reason that TRIR has been so pervasive is that there is only one government-mandated definition of a recordable injury. This strength must be replicated by creating and maintaining one definition of HECA. If organizations begin adapting HECA to meet their individual desires, HECA loses much of its utility for shared learning. Shared learning is critical for SIF elimination because no single company will figure out how to eliminate fatalities on its own. Instead, we must learn and advance together, which requires a shared vocabulary and assessment structure. Importantly, a shared vocabulary is also the underpinning of any emerging scientific field.

•**HECA should be used for learning and improving rather than measuring and comparing.** Any metric used to compare businesses, business units, projects, teams and so forth has the potential to directly or indirectly be incentivized. HECA is no exception. When incentivized, any metric can encourage poor behavior such as underreporting, misreporting, case management and other forms of data manipulation. The problem is not with the structure of the metric, but with the incentives created by the organization and external stakeholders such as investors. To ensure that HECA has the greatest positive impact, it should be used for continuous safety monitoring, learning and strategic allocation of resources.

•**HECA should be strategically operationalized to ensure long-term success.** The purpose of this article is to describe the initial concept of HECA and the strict definitions of high energy and direct control. Future work is needed to operationalize HECA and create guidance on sampling methods required to have a representative data set, methods to collegiate HECA to various stakeholders, methods to analyze and report HECA, opportunities for shared learning across communities, and approaches to independent validation.

•**The relationship among leading, lagging and monitoring variables (e.g., HECA) should be empirically explored.** Metrics are only useful if they tell a story that enables better discussions that yield more effective decisions. By understanding the potential relationships among leading indicators (inputs), HECA (system monitoring) and lagging indicators (outputs), there may be a future where collective metrics suggest what to change and by how much, what will be seen in the field, and what to expect for long-term outcomes. As a system monitoring variable, HECA would play an important role in regular surveillance and control and may be predictive in nature.

•**Although HECA still needs work, it is an important step toward a future where safety metrics are aligned with safety principles.** The safety community has made strides through concepts of human and organizational performance, but primary safety metrics (e.g., TRIR) remain antithetical and antiquated. HECA offers a new, intentionally designed method of assessing safety performance that is aligned with current safety principles and may enable continuous monitoring and strategic decision-making. More work is needed to understand HECA in practice, such as sampling frequency, independent validation and prevention of manipulation. PSJ

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