Leading & Lagging Indicators

Do they add value to the practice of safety?

By Fred A. Manuele

CAN A SOUND CONCEPTUAL BASE be established that supports the use of leading and lagging indicators in the practice of safety? Does use of the terms add substance and value to the work of SH&E professionals? A literature review was conducted in an effort to answer these important questions. The process led to an article reporting that Massachusetts Institute of Technology (MIT) researchers had developed measures to predict performance of complex systems (Gaseau, 2007). That article became influential in the author's thinking about leading indicators.

> Taking a cue from the financial world, MIT researchers along with experts in industry and government have developed a list of 13 measures that engineers can use to predict how well a system or a project will perform before it is even finished. Known as leading indicators, analogous measures are regularly used by economists, investors and businesses to help predict the economy's performance.

The procedure requires that statistical performance measures be applied to the elements in the system and that predictions be made of "how well a system or a project will perform." In other uses of the term *leading indicators,* it was also found that numerical measures are established to assess whether the goals to be achieved by applying the leading indicators are met.

Significantly, the MIT researchers acknowledged that the measurement system they created was based on techniques used in the financial world. The MIT document prompted a journey of inquiry into the financial field. Economics-related literature on leading and lagging indicators is abundant, as the following definitions reflect.

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Definitions From the Economics Field

Leading Indicators

As defined by Answers.com, a leading indicator is a measurable economic factor that changes before the economy starts to follow a particular pattern or trend. Leading indicators are used to predict changes in the economy, but are not always accurate.

As defined by About.com, a leading indicator is an economic measure that changes before the economy does. Changes in leading indicators may predict the course the economy is to take in the future, although not with great accuracy.

Examples of leading indicators include trending (e.g., increases, decreases, stasis—state of no change) with respect to the production work week, building permits, unemployment insurance claims, the money supply, inventory changes and stock prices.

Lagging Indicator

As defined by About.com, a lagging indicator is a measure that only changes after the economy has changed. It is of little use in looking ahead. However, lagging indicators are helpful in confirming a trend.

As defined by InvestorWords.com, a lagging indicator is an economic indicator that changes after the overall economy has changed.

Examples include the unemployment rate, labor costs, business spending, the prime rate, outstanding bank loans and inventory book value.

Observations to This Point

Based on this information, several observations are made with respect to leading indicators:

- Pertinent measurable activities are selected for observation.
- Statistical trends are recorded and analyzed.
- Predictions are made of future performance before the performance changes occur.
- Forecasts may not be accurate.

It is doubtful that safety management processes can be selected as leading indicators for which directly related incident trends can be developed and statistical predictions made of the incident experience in the future. Note also that the system developed and used by economists does not result in accurate predictions for the future. Are SH&E professionals that much more sophisticated that they can choose and trend leading indicators and make more accurate predictions with respect to reductions or increases in incident frequency and severity?

Questions About Accuracy in Selection

In a conference slide presentation, Marlowe and Skrabak (2007) suggest that SH&E professionals have not yet arrived at the level of sophistication suggested. They pose two questions:

1) How do you know that a leading indicator means anything?

- Inference
- Faith

2) How can I find out?

- Patience (On the slide, Marlowe and Skrabak show an image of hands clasped in prayer.)

Marlowe and Skrabak (2007) imply that the selection of leading indicators is largely judgmental and only time will tell whether the indicators selected are the right ones. It seems logical to suggest that the leading indicators selected should relate directly to opportunities to reduce risk by improving those safety management processes that analysis indicates need improvement, on a prioritized basis. As Berra (1998) appropriately notes, "Making predictions is hard, especially when they are about the future."

Toellner (2001) similarly implies that the state of the art for selecting leading indicators in safety may not be at a high level. Toellner discusses a major construction project in which the management team used leading indicators, and for which the progression for incident experience was commendable. Indicators selected were toolbox safety meetings held at the beginning of each shift; housekeeping; barricade performance for elevated areas; and management walking around to show leadership and commitment. Injury reduction was notable.

However, Toellner says, "one can debate how much of this improvement is directly linked to use of leading indicators. The management team and workers had a desire to improve and likely would have shown improvement without the process."

In safety-related literature, the most commonly identified lagging indicators are accidents and cost trends, and sometimes near misses. Definitions of lagging indicators in the economics field say they are measures of changes that occur "only after the economy has changed." That is an important premise. It implies that lagging indicators trail and are moved by earlier economic changes. Statistically predicting upward or downward movement in accident trends and costs and relating them specifically to revisions that occur in safety management processes would be difficult.

The Balanced Scorecard

In March 2007, ASSE held a symposium on measuring safety performance. Speakers discussed scorecards, dashboards and other reporting systems. All of these systems contain data advising management on whether performance goals with respect to safety management processes are being met.

Gerald Turner, P.E., CMC, senior associate at The Balanced Scorecard Institute, was a keynote speaker at that symposium. His speech about using the balanced scorecard to achieve safety and health performance excellence was based largely on books written by Robert Kaplan and David Norton.

One of those books, *The Balanced Scorecard: Translating Strategy Into Action,* published in 1996, was an early treatise on how applying both leading and lagging indicators could be significant in achieving management goals. Many companies have adopted a version of the balanced scorecard or a comparable system, and that has brought some SH&E professionals into the process.

The name of the process itself reflects, among other things, the need for a balance between the use of lagging and leading indicators. In the balanced scorecard approach, a business unit's mission and strategy are translated into tangible, measureable objectives. A balance is to be maintained between the outcome measures, the results from past efforts (the lagging indicators) and the measures that drive future performance (the leading indicators.) Operational processes are selected for emphasis "that are most critical for achieving breakthrough performance" (Kaplan & Norton, 1996).

For the practice of safety, this implies that the critical processes can be, and have been, identified and that statistical indicators for breakthrough performance can be developed. This idea, focusing on the processes most critical with respect to hazards and the risks that derive from them, would enhance the effectiveness of a safety management system.

Safety practitioners who write about leading and lagging indicators seldom indicate that they have identified and focused on critical operational processes. Nor do they incorporate statistical progress measures in their systems. It would be good safety management if the so-called leading indicators selected monitor the effectiveness of control systems that are "most critical for achieving breakthrough performance."

On Incident Data

In his speech, Turner recognized the "common challenges" encountered in applying leading indicators in the practice of safety. He spoke of the conceptual problems since measuring the effects of the selected tactics may be difficult. Turner observed that since there are multiple causal factors for most accidents, choosing the relative leading indicators, the issues for which improvements are to be made in safety management processes, becomes complex.

As noted, the most commonly identified lagging indicators are accidents and cost trends, and some-

Abstract: *The terms* leading indicators *and* lagging indicators *are common in safety literature, but information on their origins, definitions and use is rare. This raises the question of whether they are applicable in the practice of safety. A review of the literature prompts additional questions: Can a sound conceptual base be established that supports the use of leading and lagging indicators in the practice of safety? Does use of the terms add substance and value to the work of SH&E professionals?*

times near misses. It is commonly stated in the literature that lagging indicators provide rearview mirror data, have a low level of confidence in predicting performance, and are inadequate as measures of the effectiveness of safety management processes.

Having low-incidence and lost-workday case rates does not give assurance that a superior safety management system is in place, particularly with respect to preventing low probability/serious consequence events. But, a significant opportunity is missed if incidents are not analyzed to determine their causal factors and, thus, identify some significant shortcomings in safety management processes.

Analyses of incident investigation reports that identify causal factors can provide meaningful information on inadequacies in safety management processes and in selecting and prioritizing the processes, the leading indicators, for which improvement should be made. If interventions chosen do not relate to those inadequacies, the selection methods are questionable and the interventions may be misdirected.

During a speech at a safety conference hosted by the Association for Iron and Steel Technology in October 2008, Don Daily, president of Gallatin Steel, discussed the use of incident analysis data.

> Why is it important to conduct thorough accident/incident investigations? You can learn from accidents and incidents. Injuries are "lagging" indicators, in that they already happened. However, if we consider them in terms of the probability of similar future incidents and use what we learn from them to change our processes, then we are treating them as "leading indicators."

These are astute observations. Injuries are so-called lagging indicators, and changes in processes deriving from knowledge of their occurrence are so-called leading indicators. SH&E professionals should give Daily's comments serious thought. But does the use of the terms leading and lagging significantly affect the decision making to eliminate or reduce risks? Or are the terms unnecessary embellishments?

Lack of Clarity in Term Usage

In the literature, the selections for leading and lagging indicators can be baffling. For example, in the definitions cited earlier, the trending for "unemployment insurance claims" is a leading indicator while trending in the "unemployment rate" is a lagging indicator. That is a bit confusing.

Kaplan and Norton (1996) provide another indication of the lack of clarity in term usage.

> For certain industries, regions or market segments, excellent quality may still offer opportunities for companies to distinguish themselves from their competitors. In this case, customer-perceived quality measures would be highly appropriate to include in the Balanced Scorecard's customer perspective. Quality measures for manufactured goods could be measured by incidence of defects, say parts-per-million defect rates [among others], as measured by customers.

If accidents are lagging indicators, are quality defects per units produced not also lagging indicators? Hopkins (2007) examines process safety indicators and he questions what lagging indicators lag behind. In the relative safety literature, accidents are often referred to as "after-the-fact" events that lag behind the management decisions that impact the safety management system. Is it not also true that implementation of chosen leading indicators lags behind those same decisions?

In his important work on understanding the use of the terms leading and lagging indicators, Hopkins (2007) comments on two reports in which these indicators are discussed:

- The Baker Report (Report of the BP U.S. Refineries Independent Safety Review Panel), which was developed after a 2005 catastrophe at a BP location in Texas City, TX;
- Developing Process Safety Indicators, a report of the U.K. Health and Safety Executive.

Hopkins observes that the distinction between leading and lagging indicators in those documents is difficult to establish and that whether the subjects selected are called leading or lagging indicators is essentially irrelevant. Hopkins makes the case convincingly that "there are circumstances in which so-called lag indicators are perfectly good indicators of how well safety is being managed, and circumstances in which they are not." He concludes:

> I have examined the meaning of the terms "leading" and "lagging" in two recent influential publications and found that they are not used with any consistency. Nor do I think there is much point in trying to pin down a precise meaning since in different contexts these terms are used to draw attention to different things. Whether they be described as a lead or a lag is ultimately of little consequence.

In an e-mail exchange, Hopkins indicates that his "paper has prompted a vigorous debate." That is not surprising. It can be expected that SH&E professionals who are deep into leading and lagging indicators will resist criticism of their systems and will also be resistant to change. As an indication of the possible impact of its message, Selders wrote after a review of Hopkins' paper, "It is a great discussion and gets one to think about leading/lagging indicators. What is one person's lagging indicator may be another's leading indicator."

Eckhardt (2002) also expresses concerns about the practicality of using leading indicators as predictors and the difficulty in determining what is or is not a leading indicator.

> As in any attempt to determine an accurate method of measurement for a complex subject, the science of measuring safety is to a significant extent an art due to the considerable guesswork involved. Because so many vari-

ables in the workplace affect the accident rate, the main problem in using leading indicators is that an accurate forecast is not easily determined. For example, changes in management commitment, financial pressures, overtime hours, quality and levels of training, layoffs and/or the number of new hires, equipment changes, variations in levels of maintenance, ad infinitum affect the accident experience. With the behavioral movement, many companies began measuring safety by recording the number of observations of unsafe behavior noted during behavioral reviews. Proponents of this system argued that because the indicator was not based on actual injuries, it was a more effective means of measurement. The fact remains: recordings and documentation within the system occur following observation of the relevant behavior. Behavioral observations, therefore, are also trailing indicators.

Questions about definitions and applicability of leading and lagging indicators in the practice of safety are valid. Has the profession created definitions that are not soundly based, definitions that will not withstand inquiry as to origin, substance and application?

Adding to the Confusion

Assume that an analysis of incidents which have resulted in harm or damage, and of near misses, shows a continuing deterioration in an operation's mechanical integrity. The substance of the analysis becomes a leading indicator in that it is predictive since it informs management that the risk has increased, meaning that the probability of a hazard-related incident or exposure occurring that could result in serious harm or damage has increased. Therefore, although an analysis of the lagging indicators—trending of incidents and near misses—can be a leading indicator, the incidents and near misses are called lagging indicators. At some point, is it not appropriate to suggest that this differentiation becomes gibberish?

In the practice of safety, are some leading indicators derivatives of other actions and, therefore, trailing indicators? Assume that the preventive maintenance system to maintain the mechanical integrity of a process deteriorates. The deterioration more than likely is an effect from some causal factor, such as a budget cut that reduced the maintenance staff. The deterioration is a lagging indicator, an outcome that lags behind the decision to reduce staff. But, the deterioration is also a leading indicator in that it may be predictive of an increase in risk.

Cause & Effect Relationships

Kaplan and Norton (1996) make much of establishing cause-and-effect relationships and testing the hypothesis on which the leading indicators are based. They say that "the scorecard should be based on a series of cause-and-effect relationships derived from the strategy. Periodic reviews and performance monitoring can take the form of hypothesis testing." (Hypothesis: theory, premise, proposition, assumption. Strategy: plan of action, tactic, method.)

In that context, the expected outcome of the application of a leading indicator would be identified and declared, and in an appropriate time, it would be subjected to a cause-and-effect test. For example, assume that $1 million is to be spent on defined sales promotion initiatives and the goal is to increase sales by $20 million. At a later date, the hypothesis test would determine whether the numerical goal for increased sales was reached. If not, the premises on which the expenditure proposal was based could be called into question due to a lack of a cause-and-effect relationship.

In the practice of safety, the leading indicators chosen would be the safety management processes to be improved so that risks and incident frequency and severity are reduced by a specified amount. However, it must be recognized that it is difficult for SH&E professionals to establish numerical cause-and-effect relationships directly related to the leading indicators chosen. Those relationships are seldom found in the literature. Haight and Thomas (2003) comment on their absence:

> Most of the literature [referring to leading indicators] does not contain mathematically or scientifically supported evidence that shows a quantitative relationship between the "indicators" and prevention of accidents.

Safety professionals delude themselves if they presume that they can be close to accurate in making numerical predictions of the outcomes that are to result from management giving particular direction to the selected leading indicators.

An Informative Publication on Leading & Lagging Indicators

Particular attention is given here to a publication that gives specifically related guidance on determining and applying leading and lagging indicators in the practice of safety: *Process Safety Leading and Lagging Metrics,* published by the Center for Chemical Process Safety (2007).

Three types of process safety performance metrics are described and the text on their selection and application is extensive. The metrics are lagging metrics, leading metrics, and near miss and other internal lagging metrics. The metrics pertain only to chemical process incidents and near misses, to the exclusion of types of incidents that are not process related.

The leading process safety metrics to be given particular attention "were selected based upon the experience of the organizations represented in the workgroup." They are:

- maintenance of mechanical integrity;
- action items follow-up;
- management of change;
- process safety training and competency (and training competency assessment).

In the history of the chemical and petroleum industries, causal factors for major events have often related to inadequacies in these four management

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processes and it is understandable that the study group that produced the document chose them as focus points. But, the text also says:

> Companies should identify which of these components are most important for ensuring the safety of their facilities, and should select the most meaningful leading metrics from the examples [above], and where significant performance improvement potentially exists. Other leading metrics may be defined as well if applicable.

Thus, the point is that interventions selected should be most meaningful and have potential to improve performance. The text implies that an audit be performed to measure trends with respect to the four management systems and other leading indicators which may be chosen. It is also implied that performance standards are in place against which auditors can make evaluations. No reference is made to numerical predictions of future performance.

The publication contains a separate section on near-miss reporting and other lagging metrics:

> Since a near miss is an actual event or discovery of a potentially unsafe situation, this metric could be defined as a "lagging" metric. A large number or increasing trend in such events could be viewed as an indicator of a higher potential for a more significant event; therefore, many companies use near miss metrics as a surrogate for a "leading" metric.

A near miss is described as "an undesired event that under slightly different circumstances could have resulted in harm to people, damage to property, equipment or environment or loss of process." Trend data showing increases in near misses (lagging indicators) "could be viewed as an indicator of a higher potential for a more significant event" and, thus, be considered a surrogate for a leading indicator.

A surrogate is a substitute, replacement, proxy, stand-in or deputy. Companies that use near-miss metrics as a surrogate for a leading metric are aware that tracking near-miss trends can produce "a forward looking set of metrics which indicate the performance of the key work processes, operating discipline, or layers of protection that prevent incidents." That quote is the definition of a leading indicator in *Process Safety Leading and Lagging Metrics.* Thus, metrics on lagging indicators, near misses in this instance, also can be leading indicators.

If metrics that track near misses can be classified as leading indicators, it is not feasible to conclude that metrics tracking accidents also can be classed as leading indicators?

Since the SH&E professional's function is to give counsel to achieve acceptable risk levels, it is not advantageous to confound discussions of risk with vague, intermediary terms.

Are the Terms Leading & Lagging Indicators Needed?

Whether the terms leading and lagging indicators add value in the practice of safety is questionable. Consider these two examples from the literature.

Russell (2007) discusses the use of metrics, focusing on a "loss cost" sequence. In his 18-page paper, the terms lagging and leading indicators appear in the introduction, in two figures and in the conclusion; they do not appear elsewhere in the text. Use of the terms would not have added value to the substance of the paper.

Russell appropriately says that "it is important to assess, diagnose, research and study the evidence in order to predict and prescribe effective safety interventions." He stresses deciding on interventions that will reduce risks, choosing the right interventions, the need to have a risk assessment process in place, and testing the hypothesis on which interventions are based through subsequent analysis.

Parameshwaran, Haight, Del Castillo, et al. (2004) examine intervention effectiveness research, focusing on understanding and optimizing industrial safety programs using leading indicators. This work gives substance to the validity of questioning whether the terms leading and lagging indicators are needed and whether they add value to or detract from the legitimacy of the practice of safety. The term leading indicators appears in the title and abstract of this research article, but nowhere else. The terms were not needed in the discussion of how intervention effectiveness was analyzed.

An Appropriate Course of Action

Fundamentally, the language of safety practitioners should focus on hazard identification and analyzing the risks associated with those hazards, followed by giving prioritized counsel on improving safety-related management issues to achieve acceptable risk levels.

To better understand the management issues to be addressed, ANSI/AIHA Z10-2005, Occupational Health and Safety Management Systems, gives sound guidance.

> The planning process goal is to identify and prioritize occupational health and safety management issues (defined as hazards, risks, management system deficiencies, and opportunities for improvement) and to establish objectives that offer the greatest opportunities for occupational health and safety management system improvements and risk reduction consistent with the organization's occupational health and safety policy.

Some of those management issues become apparent in the incident investigation and analysis processes. On a broader base, note that the focus commences with identifying and analyzing hazards and assessing the associated risks, then moves into a determination of the management system deficiencies that allow them to exist. Improvement actions decided on would be those that offer the greatest opportunity for risk reduction. That cannot be done if an organization's risks have not been analyzed and prioritized. In that process, analyses of incident experience can provide valuable information.

The Primary Goal

This author presents a premise as applicable to the work of all personnel who give advice to avoid

injuries and illnesses and property and environmental damage. "The entirety of purpose of those responsible for safety, regardless of their titles, is to identify, evaluate, and eliminate or control hazards so that the risks deriving from those hazards are acceptable."

Thus, a definition of acceptable risk is needed. A sound, workable definition must encompass hazards, risks, probability, severity and economic considerations. The following definition also makes clear that a risk level as low as reasonably practicable must be tolerable.

> Acceptable risk is that risk for which the probability of a hazard-related incident or exposure occurring and the severity of harm or damage that may result are as low as reasonably practicable, and tolerable in the situation being considered.

This definition incorporates the concept of ALARP, or *as low as reasonably practicable.* ALARP is that level of risk which can be further lowered only by an increment in resource expenditure that is disproportionate in relation to the resulting decrement of risk.

Communicating on Risk Levels Effectively

In communicating with decision makers on risk levels and proposed interventions in safety management systems, a risk assessment matrix should be used. A matrix provides methods to categorize combinations of probability of occurrence and severity of harm, thus establishing risk levels. It provides a base from which to determine the extent of the risk reduction to be achieved from the actions taken on the hazard/risk recommendations being considered.

Also, a risk matrix can be used to compare and prioritize risks, and to effectively allocate mitigation resources. Literature on risk assessment matrices, of which there are many models, is abundant. The example given here was developed by the author (Table 1). It should be noted that the numbers presented are arrived at judgmentally and are qualitative. They are not quantitative. The numbers are significant only in relation to each other.

Conclusion

This author's premise is that using the terms leading and lagging indicators does not add value to the practice of safety. Definitions and use of the terms, as in safety-related literature, are not compatible with the definitions in their place of origin, the field of economics, from which they have been adopted, without also adopting the discipline of their use in that field. It is doubtful that safety management processes can be selected as leading indicators for which trends can be measured and statistical predictions made about the future accident experience. It seems that a leading indicator is significant only as it relates to increasing or decreasing risk.

Since the SH&E professional's function is to give counsel to achieve acceptable risk levels, it is not advantageous to confound discussions of risk with vague, intermediary terms. SH&E professionals should understand that it is all about risk. The writers of ANSI/AIHA Z10-2005 did a good job in outlining sound problem-solving and resolution methods for improvement in occupational safety management processes. Why subordinate a sound strategy with unnecessary and hollow terminology that diverts attention from good occupational risk management? ■

Table 1

Risk Assessment Matrix

	Occurrence probability and values				
Severity levels and values	**Unlikely (1)**	**Seldom (2)**	**Occasional (3)**	**Likely (4)**	**Frequent (5)**
Catastrophic (5)	5	10	15	20	25
Critical (4)	4	8	12	16	20
Marginal (3)	3	6	9	12	15
Negligible (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Very high risk: > 14; high risk: 9-14 ; moderate risk: 4-8; low risk: < 4

Note. *It should be noted that the numbers presented are arrived at judgmentally and are qualitative. They are not quantitative. The numbers are significant only in relation to each other.*

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