Towards a framework for steering safety performance: A review of the literature on leading indicators

Seyed Sajad Mousavi[1,*], Elizabeth A. Cudney[2] and Paolo Trucco[1]

[1] Department of Management, Economics and Industrial Engineering, Politecnico di Milano
Milano, Italy
[2] Department of Engineering Management and Systems Engineering, University of Missouri
Rolla, U.S.A
{seyedsajad.mousavi}@polimi.it

Abstract. While remarkable progress has been made recently to improve the state of occupational safety, the number of occupational accidents is still unacceptable. In addition, the organizational costs related to these safety problems in the workplace are staggering. Therefore, effective strategies are needed to guide the continuous improvement of safety performance. Common approaches include setting safety goals, identifying the key activities/interventions to reach those goals, and evaluating performance. The most challenging and fundamental issue within these approaches is evaluating safety performance. While it has been a focus of safety professionals, concerns still exist among researchers with regard to how safety performance can be appropriately and accurately measured to improve decision support systems. Recently, researchers in the field of safety have begun directing efforts towards new approaches for measuring safety performance by addressing leading indicators. However, because of its nature and utility, the ideas and concepts of leading indicators have remained unclear. In an effort to overcome this challenge, this study attempts to distinguish between the two common aspects of safety performance, observable activities and outcomes. The importance of using leading indicators for steering safety performance is then highlighted. In order to meet these objectives, the results chain model, which has been introduced by several researchers for outlining the program development, is employed. The elements of the results chain model are then interrelated with relevant safety concepts. As a result, the relationship between the leading and lagging indicators and safety performance is identified. A set of leading indicators that predict safety performance is proposed. Further, the important implications of this study for both academic communities and practitioners are discussed as well.

Keywords: Safety performance · Leading indicators · Results chain model · Literature review

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1 Introduction

The vision stated by the National Institute for Occupational Safety and Health (NIOSH) highlights the importance of healthier and safer workers' role in promoting productivity in the workplace [1]. This vision is addressed in literature where several researchers discuss the advantages of safer and healthier workplaces including more productive workforce, improved financial performance, and lower healthcare costs [2], [3]. In contrast to the advantages of following OHS principles, significant problems can occur as a result of ignoring those rules. For example, nearly 6,000 deaths and approximately four million work-related injuries and illnesses are reported each year in the United States [4]. These problems affect both the employers and employees. While the organizational cost relative to poor safety at work is incurring, employees' families are also indirectly suffering from overlooking OHS principles in the workplace. Annual costs of more than $53 billion for workers' compensation have been reported by the United States Department of Labor [5]. Therefore, addressing OHS concerns can be a significant step in a companies' attempt to affect not only the companies' performance but also society.

Further, due to rapid changes in technology, new hazards have been brought in to the workplace. Subsequently, safety professionals should modify approaches to measure safety performance more appropriately; even though remarkable progress has been made to improve the state of occupational safety in the workplaces compared to the past. For instance, the number of deaths in 1912(21,000) dropped to 5,000 in 2014 [4]. Despite this striking progress, there is still a need for establishing new strategies to control and reduce workplace risks. As an example, NIOSH recently launched the Total Worker Health (TWH) program to sustain and improve the workers' health and safety in the workplace. Creating a safer and healthier workplace through establishing policies and programs is beneficial for individuals, families, and employers and their organizations, which further leads to productive communities. Although considerable studies have been conducted on the various aspects of safety and health in the workplace, less attention has been devoted to proposing a method for planning, predicting and measuring OHS performance in an integrated and systematic way. For instance, how the antecedents of safety performance are related to safety activities and their final outcomes is still controversial among scholars [4]. A comprehensive conceptual framework for illustrating the possible relationships among safety concepts is clearly needed

Further, considering preventive activities in safety can result in high return on investment. As an illustration, American Society of Safety Engineers shows that companies which spend 1$ on preventive activities in connection with workplace safety can lead to at least 3$ saved According to this fact, again, the importance of planning and predicting OHS performance is shown. Luckily, nowadays, safety programs have been directed to upstream safety efforts compared to the downstream approach in the past. Nevertheless, illustrating both upstream and downstream safety concepts in a conceptual framework is lacking.

The present study attempts to clearly and systematically illustrate the relationships among safety concepts in a comprehensive framework. To this end, a review of the literature addressing OHS indicators has been performed. Future studies can benefit of the proposed framework to develop specificand more consistent methods for measuring OHS performance in different operational contexts and according to different priorities.

The rest of the paper includes the different approaches of safety performance' measurement in the next section, then, the introduction of the results chain model is provided, next, the linkage of safety concepts to the result chain model's elements will be provided. After that, section five shows the upstream safety's concepts involving leading indicators and, lastly, implications of the study and conclusions are presented.

2 Measurement of safety performance

The foundation of a business management process includes measuring and controlling the performance. The gap between an acceptable level and current level of performance is identified by measurement [6]. Safety professionals are expected to establish similar approaches for managing safety activities and identifying appropriate interventions to create a safer workplace. In order to continuously improve the safety performance of a workplace, certain strategies are commonly employed such as goal setting, identification of the key activities/interventions to reach those goals, and performance evaluation. The most challenging and fundamental issue among these strategies is the evaluation of safety performance. Two common views exist regarding safety performance. The old view refers to blaming individuals for human errors and at-risk behaviors. By addressing this view, only humans were typically identified as the causes of accidents and injuries. As a result, the underlying indicators for measuring the safety performance within the old view included the number of accidents and injuries. Human error does not address the influencing elements behind an individual's activities or decisions. Therefore, the reasons, or root causes, that led to accidents and injuries remained unclear. After two catastrophic accidents, Chernobyl and Bhopal, researchers were warned that other elements also attributed to accidents in the workplace [7] .This limited view is not appropriate today; therefore, a new view is required.

The new view believes that the human error is a symptom and not a direct cause of accidents. It focuses on root causes of accidents such as organizational factors, task characteristics, and working environment. Compared to the traditional approach, which failed to point out the direct factors influencing accidents and injuries in the workplace, the current holistic view provides a strong rationale for recognizing and controlling the causes of accidents. This approach can help organizations prevent accidents from reoccurring. Different tools and techniques to measure safety performance have been developed using the new view compared to the traditional approaches. The common indicators, which are used to measure safety performance, are known leading indicators. These indicators address the underlying elements that had been overlooked under the auspices of human errors. For example, researchers have recently addressed the elements of safety culture, management commitment, personality, and work design as they relate to accidents and injuries in the workplace [8] and [9]. Although new methods of measuring safety performance have been introduced by researchers, clear definitions of these concepts still require additional research. Further, experimental studies are needed to test and verify the advent of new concepts within the occupational safety context.

3 Result chain model

As previously mentioned, new tools and techniques have been developed with respect to safety performance measurement under the new view. To further the new view, clear definitions of safety-related terms should also be developed. This is the main objective of the present study. This research attempts to introduce the results chain model and its application to illustrate these safety terms more effectively.

In order to evaluate the impact of a program, the theory of change was developed by policy makers [10]. The simplest and clearest model to outline the theory of change is the results chain model, which sets out a sequence of inputs, activities, and outputs to illustrate how various elements lead to the final outcomes of a program [10]. The benefits of using this model are its ability to illustrate the theory of change, measure effectiveness, and develop a framework for cross-site learning. The results chain model provides a framework for analyzing the short-, medium-, and long-term results of a program. Figure 1 illustrates the structure of this model and the five underlying components, which include inputs, activities, outputs, outcomes, and final outcomes. The results chain model is employed in four main situations. First, it helps to signify assumptions about how various strategies can lead to desired results. Second, it provides a framework for designing a monitoring plan. Next, through the monitoring plan it is possible to analyze and adapt the plan according to the defined goals and organizational demands. Finally, the results chain model can be used for external evaluations.

Fig. 1. The results chain model [10]

Descriptions of the elements within the results chain model are as follows:

Inputs: Resources at the disposal of the program.
Activities: Actions taken to convert inputs into outputs.
Outputs: Tangible results produced by activities.
Outcomes: Changes (usually short to medium time range) resulting from activities and outputs.
Final outcomes: Final goal(s) of a program (typically achieved over a longer period of time).

This model has been used in diverse contexts. For instance, the World Health Organization (WHO) stated that the results chain model is the main method they employ to assess their programs' performance [11]. In addition, researchers have utilized the results chain model to evaluate the holistic impact of a program or policy. For example, Jahanmehr et al. [12] proposed a conceptual framework using the results chain model to evaluate public health system performance in Iran. They changed the underlying components of the model and used input, process, output, and outcome as the main sections. In another study, Gertler et al. [10] provided an example of using the results chain model to evaluate the performance of a new educational approach. The components of the results chain model in their study included:

Inputs (human, financial, and other resources), activities (designing new curriculum and training teachers), outputs (textbook delivered to the classrooms and trained teachers), outcomes (improved student performance and textbook usage by teachers in the classrooms), and final outcomes (improved completion rates and higher earnings).

The result chain model is based on the objective of a study and can be employed in different contexts. In the next section, safety performance and how its underlying concepts can be interrelated within the results chain model is discussed.

4 Interrelating safety concepts and the results change model

A holistic framework embodying all safety concepts can help safety professionals clearly set safety goals, define indicators, and evaluate safety performance more appropriately. Furthermore, the new view of safety performance measurement requires a precise definition of safety concepts including safety activities, leading indicators, and antecedents of safety performance. Therefore, this research attempts to integrate the safety concepts into the results chain model by addressing the following perspectives.

The importance of the antecedents of safety performance in achieving safety goals
The role of safety activities in achieving safety goals
The position of leading and lagging indicators among safety concepts
The association between a near-miss and an accident
The function of safety behaviors among safety concepts

In order to present these perspectives, the blocks of the results chain model are employed. By using this model, a sequence of events is depicted to illustrate the relationship among safety concepts from the initial elements and antecedents of safety performance to the final elements, accidents, and injuries.

Based on the definition of an input within the model, which is in connection to the resources of the program, an antecedent is an input to safety efforts. This is supported by Wallace (2016), who states, “The people, tools, tasks, and operating environment can all be treated as inputs or antecedents of safety” [p. 2]. Additional researchers also mention antecedents of safety performance as any direct or indirect items that influence safety performance [7] and [13]. According to the safety literature, there are four common antecedents for safety performance, which include working environment, task characteristics, workforce characteristics, and organizational factors [13]-[16]. Subsequently, these four elements were utilized as inputs for the proposed model.

Activities within the results chain model are defined as any action taken on the inputs to produce an output(s). Therefore, safety activities are defined as any undertaken action(s) in connection with the antecedents of safety performance. A proper indication of safety performance in the workplace can be determined by the consistency between safety activities and safety goals. Since early efforts in safety programs are referred to as safety activities, analyzing and evaluating this element can highlight inconsistencies between safety activities and safety goals in an organization. Therefore, in order to measure the status of safety activities, OHS leading indicators have been introduced in the literature. In several studies, the term of activities indicators is used interchangeably with leading indicators [4] and [17]. For example, safety activities extracted from literature include training, risk assessment, job safety analysis, accident investigation, written information about OHS procedures, personal protective equipment, budget for OHS, and involvement of workers in setting OHS policies [18]-[20].

The next element in the results chain model is the output(s), which is described as the tangible results produced by activities. For safety, outputs are consistent with the definition of safety behaviors. Safety behaviors are the observable activities that are generated by employees (Wallace, 2016); therefore, they are classified into two categories, safety participation and safety compliance. Safety participation refers to the participation of employees in voluntary safety activities [21], such as participation in safety meetings to address safety concerns and improving OHS programs in the organization. Alternatively, safety compliance refers to following the OHS rules in the organization [22], such as using personal protective equipment and following OHS procedures. Therefore, safety behaviors are the outputs of activities that were undertaken on the antecedents of safety.

The next element in the results chain model is outcome(s), which are short or medium changes that are a result of outputs and activities. A near-miss is an unplanned incident with short-term results that does not result in an accident or injury [23]. Since this definition is consistent with the outcome's definition in the results chain model, near-miss is placed as the outcome in the proposed model. Further, a near-miss can be a transitional indicator between safety behaviors and accidents. While near-misses are defined as an outcome for safety efforts, they can also provide invaluable information for preventing future accidents. Near-misses are short-term results of safety programs despite the existing potential to become accidents or injuries since they can provide a significant alert for safety professionals. By investigating near-misses, root causes are identified and preventive action plans can be implemented.

The last element in the results chain model is the final outcome(s). This item addresses the final goals of a program. Accident and injury reduction is the final goal of safety efforts in an organization. Moreover, due to the long-term impact of accidents, injuries, and occupational disease for both the individual and organization compared to the near-misses, these can be placed in the model as final outcomes. It is worth noting that a clear distinction between accidents and injuries is provided by Wallace (2016),"Traditionally, accidents and injuries have been lumped together, yet accidents can happen in which no injury occurs such as in an instance of damage to a piece of equipment."[p.3]. Therefore, measuring these final outcomes through lagging indicators reveals the impact of safety interventions. This information is useful for management as it provides managers with details about the overall status of the safety and health programs in the organization. The final outcomes can also be used as benchmarking measures.

Based on these definitions, a results chain model with related safety concepts was developed. Figure 2 provides the proposed model for illustrating safety concepts.

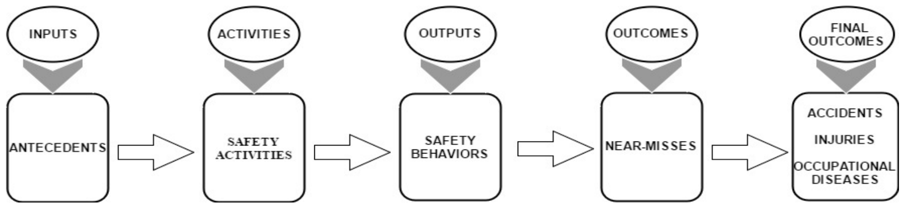

Fig. 2. Proposed model for safety concepts

5 OHS leading indicators

In this section, two additional definitions for leading and lagging indicators within the OHS context are described. Selecting the appropriate performance indicators is a critical step in safety and health program evaluation. After setting safety goals, the indicators are used to assess how consistent the activities and interventions are with safety goals. A clearly articulated framework for safety concepts provides a useful map for selecting the underlying OHS indicators along the results chain. In order to effectively monitor safety performance, two kinds of indicators are necessary: one indicator for monitoring the safety efforts and the other indicator for evaluating the result of safety efforts.

According to this criterion, two types of OHS indicators already exist, which include leading and lagging indicators. Lagging indicators measure final outcomes of activities or events [24], and, therefore, are often referred to as after-the-fact indicators [25]. Lagging indicators were in placed in the proposed model to measure the final outcomes such as accidents, injuries, and occupational diseases. Traditionally, recordable injury rate, days away, and restricted work have been introduced as lagging indicators, which are also consistent with the elements of the proposed model.

Leading indicators are known as the activities indicators, which help an organization take action(s) to lower risks [24]. In addition, according to Step-change [26], leading indicators in safety are "something that provides information that helps the user respond to changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes" [p.3]. These statements are pertinent to the activities undertaken within safety programs. Therefore, the following definition for leading indicators is proposed: something that provides information about undertaken activities on the antecedents of safety performance. Table 1 provides the underlying leading indicators that were extracted from relevant safety literature [18], [19], [20], [23], [24], [27], [28], [29], [30].

Table 1: Leading indicators linked to the antecedents of safety performance

Antecedents of safety performance	Leading indicators

Working environment	Assessment of working environment's hazards, correct tools and equipment, inspection of tools and equipment periodically, health facilities (e.g., toilet, showers), near-miss investigation, benchmarking, and audits.
Workforce	Number of employees trained on OHS principles, OHS brochures/literature, verbal instructions on OHS, personal protective equipment, and training.
Task	Job safety analyses, written information on OHS procedures, written information about safe working, and consideration of ergonomic factors.
Organizational factors	Management commitment to OHS policies, safety culture, people's involvement in articulating OHS issues, OHS budget, OHS scheduling, reward system for correcting OHS issue, management walk throughs, and contractor management.

6 Implications of findings and conclusions

The proposed model has critical implications for both the academic community and practitioners. The sequence of safety concepts provides a holistic framework, which enables researchers and practitioners to understand the causal logic behind safety events. This framework can facilitate discussions on monitoring and evaluating safety efforts by showing what needs to be monitored and evaluated. Leading indicators can be used to monitor safety efforts and lagging indicators can be used to evaluate safety programs [24], as illustrated in the proposed model. Leading indicators measure the safety activities and lagging indicators measure the final outcomes. Moreover, measuring safety activities is a self-assessment of safety performance at lower levels of an organization as opposed to lagging indicators that are used at managerial levels. By conducting self-assessments, organizations can determine how consistent their safety activities are with their safety goals. Then, corrective action(s) can provide continuous improvement for safety efforts. On the other hand, through measuring final outcomes with lagging indicators, the overall evaluation of a safety program is possible, which enables management to make decisions regarding the organization's OHS policy.

Measuring safety activities is effective for predicting future safety performance; however, predicting the outcomes itself is not necessarily possible. In other words, safety activities indicate only how effectively the safety programs are conducted. Additionally, measuring safety activities can be used to motivate and direct employees towards safe behaviors.

A combination of both leading and lagging indicators is recommended to determine appropriate safety program interventions. While leading indicators depict the safety-related activities and how well they meet safety goals, lagging indicators provide an indication of the efficiency of safety program interventions. The proposed framework integrates common safety concepts in a simple, comprehensive structure for future relevant studies.

Since safety has been defined as a process rather than an event [17], the entire safety process from the initial steps (inputs) to ending steps (final outcomes) must be considered. The proposed model maps the necessary steps to enable practitioners to monitor safety efforts by measuring safety activities and evaluating safety programs through the final outcomes.

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